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FACTORIAL STUDIES ON POTATO DUSTING MATERIALS

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Since publishing a report of experiments conducted in 1937 (1) with a "3-way" dust mixture consisting of pyrethrum, rotenone, sulfur and Bancroft clay compared with these materials used separately, experiments have been continued with this mixture and also efforts have been made to determine which ingredients are most essential. Some other materials have been included, particularly as it was desirable to know whether a copper fungicide might be added to such a mixture without injuring but perhaps increasing its insecticidal value. All of these experiments have been located in areas on Long Island where insect control is of primary importance in most years. In these areas bordeaux mixture not infrequently has [illegible] in hot, dry summers.

Red copper oxide was the fung[illegible] ome of the combinations. To determine the c[illegible] y of these materials singly and in all possible [illegible] made to an experiment of factorial design. All of the materials were tested at two levels of concentration, namely; some and none.

EXPERIMENTAL METHODS

All of the materials were mixed in a spiral type mixer at the beginning of the work and used throughout the period of the experiment. The materials were made up to contain the following concentrations of

active ingredients in the finished dusts: Pyrethrins*—0.05 per cent; Rotenone—0.75 per cent; Sulfur—35 per cent; and Red Cuprous Oxide—6.0 per cent.** Bancroft clay was used throughout as the diluent, and to every mixture was added 1 per cent Vatsol—OS.

All of the dust applications were made with an 8-row duster mounted on the drawbar of a tractor and operated by a power take-off. The dust materials were applied at the rate of 35 pounds to the acre. A 30-foot canvas trailer was dragged behind the duster to reduce to a minimum the drifting of dust from one plot to another. Four applications at approximately 10-day intervals were made during the growing season.

The factorially designed experiment included 16 distinct treatments or dust mixtures. The experiment was replicated twice and the plots were randomized within blocks. The whole field was dusted once early in the season with calcium arsenate for the control of Colorado

Experimental Results

TABLE 1.—*Showing design of experiment, final yields and insect data on potato dusting experiment. Huntington, L. I.,* 1939

Experimental Design					Total Insect Counts for Two Dates of Collection				Yield
No.*	P	R	S	Cu_2O	Leaf-hopper	Flea Beetle	Tarn. Pl. Bugs	Aphids	Bu./Acre
1	—	—	—	—	756	1264	828	8868	142.5
2	—	—	—	+	412	892	664	5532	150.5
3	—	—	+	—	340	821	380	4548	164.5
4	—	—	+	+	156	398	424	2540	169.5
5	—	+	—	—	504	541	592	3892	168.6
6	—	+	—	+	452	380	750	4368	220.0
7	—	+	+	—	330	724	468	2092	163.3
8	—	+	+	+	182	262	434	2786	231.0
9	+	—	—	—	208	1060	736	9008	205.5
10	+	—	—	+	400	496	616	2416	179.5
11	+	—	+	—	272	980	400	7948	186.1
12	+	—	+	+	212	592	404	3492	200.8
13	+	+	—	—	320	802	480	3872	166.7
14	+	+	—	+	516	352	744	2636	212.0
15	+	+	+	—	176	540	342	1650	211.0
16	+	+	+	+	130	178	356	1172	183.0

*P = Pyrethrum, R = Rotenone, S = Sulfur and Cu_2O = Red Cuprous Oxide.

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*We are much indebted to the following commercial firms for contributions of materials: John Powell & Co., New York City (Stimtox A); Co-op. G.L.F., New York City (Rotenone); American Cyanamid & Chemical Corp., New York City (Vatsol); Röhm & Haas, Philadelphia, Pa., (Red Copper Oxide); United Clay Mines, Trenton, New Jersey (Bancroft Clay).

**Six per cent Cuprocide GA analyzing 86 per cent metallic copper.

potato beetles. Insect collections were made twice during the summer by sweepings with an insect net. Fifty sweeps were made on all plots at each collection. Yield records were taken by harvesting 1/25 of an acre from each replicate, or approximately 1/12 of an acre for the individual treatments.

The season was extremely dry, therefore no blight occurred, and the injury to the plants was caused mainly by insects.

All data on yield and insect populations as shown in table 1, were subjected to analysis of variance. Instead of presenting the complete analysis of variance data for each item, comparisons of treatment effects and significant differences are given in table 2. Significant differences are given in bold type and correspond to significant F values.

TABLE 2.—*Comparison of treatment effects*

Effects	Yield	Leaf-hoppers	Flea Beetles	Tarn. Pl. Bugs	Aphids
Main:					
		Increase or decrease due to treatment.			
P*	**+16.8**	**— 56.1**	— 15.1	— 28.8	— 152.0
R	**+19.6**	— 9.1	**—157.7**	— 15.4	**—1367.7**
S	+ 8.0	**—110.7**	— 80.7	**—137.6**	— 448.9
Cu	**+17.3**	— 27.9	**—198.8**	+ 10.4	**—1052.3**
Interactions:					
		Increase "together" over "separately".			
SxP	— 3.7	+ 28.8	+ 28.2	+ 9.6	+ 430.8
SxR	— 2.7	— 11.0	+ 34.4	+ 16.8	+ 14.2
SxCu	— 2.4	— 26.8	— 5.4	— 6.8	+ 277.5
PxR.	**—19.3**	+ 15.2	+ 13.2	— 11.4	— 325.0
PxCu	—15.7	**+ 63.1**	+ 21.6	+ 9.8	— 536.1
RxCu	**+.16.9**	+ 2.16	+ 19.4	+ 39.0	**+ 990.5**
Sig. Diff.					
	±16.18 Bu./A.	± 46.9	±100.5	± 56.8	± 850.0
			Insects per 50 sweeps.		

*P = Pyrethrum, R = Rotenone, S = Sulfur, Cu = Cuprous oxide.

With respect to final yields it will be noted (table 2) that pyrethrum, rotenone and red copper oxide gave significant yield increases, whereas sulfur did not. There are two important interactions: namely, pyrethrum x rotenone and rotenone x copper. In the case of pyrethrum x rotenone, singly, either material gave a marked increase in yield in the absence of the other, but there was no increased response when both were used in the same mixture over that of either one used alone. On

the basis of yield there would then appear to be no advantage of using these two materials in the same mixture. In the absence of insect or other data one would be inclined to interpret this as indicating that both materials were operating on the same factor and presumably to the same extent or degree. This, however, does not appear to be the case on the basis of the insect data obtained, since pyrethrum was effective against leafhoppers only, whereas the rotenone was acting upon the flea beetles and aphids. The other interaction, rotenone x copper, shows the opposite trend, namely, that the two materials together were significantly better than the sum of the increases due to these materials when used alone. This trend may be noted in table 1 where nearly all rotenone-copper combinations gave the best yield response.

The interaction between pyrethrum and cuprous oxide which approaches significance rather closely is especially interesting in view of the fact that it corresponds with a significant interaction between these materials in the leafhopper control. In other words, the observed effect of pyrethrum and cuprous oxide on leafhopper control in this case might very well explain the yield obtained with different combinations of these materials.

	Average Leaf-hopper Counts	Average Yields
Without pyrethrum or cuprous oxide	241.3	159.7
Pyrethrum without cuprous oxide	122.0	192.3
Cuprous oxide without pyrethrum	150.3	192.8
Pyrethrum plus cuprous oxide	157.3	193.8

It may be remarked that the interaction appearing in table 2 results from the fact that additive effects are not obtained with these materials, *i. e.*, both together were no better than either alone, either in respect to leafhopper control or increasing yields. The fact that there were no other significant interactions may of itself be considered significant, since when there is no significant interaction it would mean that the materials were acting independently and additively.

The yields in this experiment may also be considered as a comparison of 15 different dust mixtures with a check. As there were only two plots dusted with each mixture the difference in yield required to be significant is rather high, namely, 46 bushels per acre. Considered in this way there were six mixtures which gave significant increases over the undusted which yielded 142.5 bushels; namely,

Rotenone, Cuprous oxide and sulfur......	231	bushels	per	acre
Rotenone and Cuprous oxide	220	"	"	"
Rotenone, Cuprous oxide and pyrethrum..	212	"	"	"
Rotenone, Sulfur and pyrethrum	211	"	"	"
Pyrethrum	205.5	"	"	"
Cuprous oxide, pyrethrum and sulfur....	200.8	"	"	"

It may be noted that all of the possible combinations of three out of the four ingredients are included in this group. The combination Rotenone and Cuprous oxide occurs most often. Although this experiment was not extensive enough to determine which one of these mixtures was best, several of them gave 70 to 90 bushels per acre increase in yield, even during the past rather dry summer, without irrigation. Further trials will be necessary to establish which combination is most promising or perhaps which will be advisable under the different conditions of climate and insect infestations that occur.

Pyrethrum and sulfur gave significant decreases in leafhopper populations, with the sulfur being approximately twice as effective as pyrethrum in this respect. If the yield increase from pyrethrum were due to leafhopper control (as it appears), then the lack of yield response with sulfur is rather conspicuous. There is only one important interaction between materials in leafhopper control, and the relation of this interaction to yield has been discussed above.

Rotenone and copper were the only two materials which significantly reduced the population of flea beetles. There were no significant interactions. With respect to the tarnished plant bugs, sulfur was the only material having any effect upon their numbers. As seen from table 2 sulfur is very effective in the control of this insect.

Rotenone and red copper oxide were the only materials used which resulted in significantly smaller aphid populations on the plants. The reduction of aphids by the use of rotenone is in line with similar experience in the past. The effect of the red cuprous oxide in this experiment appears to be nearly as great. Because such an effect has not previously been observed with this material, these results should be regarded as needing confirmation. They are to be contrasted with the usual effect of bordeaux mixture in resulting in an increase in aphid populations on potatoes (2). In this case the significant interaction between rotenone and cuprous oxide means that when the two materials were used together the control was only slightly better than when either material was used alone rather than having additive effects. Aphis con-

trol in some seasons may be very important since commonly in hot, dry summers aphids build up to a population of 20,000 to 40,000 per plant.

In conclusion, it may be stated that in no case did the value of the insecticides used seem to be impaired by the addition of the fungicide. In fact, the material added as a fungicide, cuprous oxide, appeared to have some value also as an insecticide, *i. e.*, in the absence of pyrethrum it reduced leafhoppers, it reduced flea beetles whether or not other materials were used and in the absence of rotenone, small counts of aphids were obtained with the use of red copper oxide. It did fail to give additional control of leafhoppers when used with pyrethrum and failed to give additional reductions in aphids when used with rotenone.

Results of Large Scale Tests in 1939

In a large scale experiment a "3-way" dust was compared with the same dust lacking the rotenone, with a pyrethrum spray and with a control.

The dusts were applied at the rate of 35 pounds to the acre at each application with a tractor drawn 10-row cyclone-type duster operated by a power take-off. The pyrethrum spray was applied with a 10-row Bean sprayer mounted on a truck chassis. The spray and dust applications were always made on the same day. Starting about the 1st of July, three applications were made at 10-day to 2-week intervals during the summer. The experimental plots were properly randomized and the final yields given represent the average of six replications, each of which was about one-tenth of an acre in area. The entire field was irrigated five times during the summer with a portable pipe irrigation system. Insect collections were obtained by sweepings with a net.

It is evident from table 3 that these various dusts affected markedly the population of the various species of insects. Leafhoppers (*Empoasca fabae* Harris) were particularly numerous and most of the visible injury on the check plants was due to leafhopper feeding or hopperburn. The new growth continuously formed, due to the frequent irrigations, seemed to form an especially attractive pabulum for this insect.

There were 2 or 3 species of plant bugs collected in the sweepings, but no attempt was made to segregate them into species. The common potato tarnished plant bug was, however, found to predominate in these counts. Potato leafhopper control is in line with what we have obtained in a previous year (1937). The aphis and flea beetle control obtained with these materials was rather surprising. The check plants died the

TABLE 3.—*Effect of some potato dusting materials on insect populations —Riverhead, L. I.—1939*

July 21st Treatments	Flea Beetles	Aphids	Tarn. Pl. Bugs	Leaf-hoppers
Check	1,922*	2,464	125	128
a) Pyrethrum spray	1,344	1,376	72	32
b) 2-way dust	408	364	52	60
c) 3-way dust	265	145	49	28
July 29th				
Check	624	6,704	432	664
Pyrethrum spray	560	3,470	215	120
2-way dust	308	1,848	88	192
3-way dust	159	723	60	59

*Counts represent 50 sweeps of an insect net.
a) A Penetrol—Pyrethrum spray miscible in water (diluted spray contains 0.0075% pyrethrins). Test product prepared by John Powell & Co., New York City.

b) Pyrethrum (Stimtox A) .... 15 pounds
Sulfur (325-mesh) .... 35 "
Bancroft Clay .... 50 "

c) Pyrethrum (Stimtox A) .... 10 "
Timbo root (5%) .... 15 "
Sulfur (325-mesh) .... 35 "
Bancroft Clay .... 40 "

earliest, and were followed closely by the death of the pyrethrum-sprayed plants. The check plants died about 3 weeks in advance of the dusted plants, with the 3-way dusted plants remaining green a few days longer than did the 2-way dusted plants. The contrast between the 3-way dusted plots and the check was quite striking toward the end of the growing season. Whereas the check plants died prematurely from hopperburn or hopper injury the 3-way dusted plants showed very little hopper injury at any time and died from other causes, primarily leaf spotting diseases caused by *Alternaria solani* and *Botrytis* sp.

TABLE 4.—*Final yield of Green Mountain potatoes in bushels per acre at Riverhead, L. I.—1939*

Treatment	Yield in Bu./Acre
Check	335.7*
Pyrethrum spray	363.3
2-way dust	397.2
3-way dust	410.5

*Minimum difference required for significance with odds of 100:1 = 21.9 bushels.

Statistical analysis of the yield data showed a high significance for treatments (F value = 43.4). All the treatments gave a significant increase in yield over the check, but there was no significant difference in yield between the two dusts. Even though these yields may appear rather high for a dry season such as 1939, it must be remembered that these plots were watered five times during the summer. For this same reason treatment differences are likely to be more outstanding since the plants were not killed prematurely from dry weather. But even under these conditions the dusted plants died from causes other than insect injury as stated previously.

On the basis of insect populations (as revealed in table 3) one would hesitate to attribute the success of the 2-way or 3-way dust to leafhopper control alone, since the total insect population is much reduced by these treatments. The fact that the check plots at the time of death showed 100 per cent hopperburn inclines one to the view that leafhopper control was a rather important factor in the increased yields obtained.

Conclusions

These results tend to confirm results of previous work in 1937 (1). The "3-way" dust consisting of rotenone, pyrethrum and sulfur and several other mixtures have given increases in yield from 70 to 90 bushels per acre even in a dry year. In the previous test the increases in yield appeared to be principally attributable to the use of rotenone and pyrethrum. Similarly this year the main effect on yield seems to be due to rotenone, pyrethrum and cuprous oxide. Sulfur again failed to show significant effects on yield.

These increases in yield appear to be related to some extent with the insect control by these various materials. Pyrethrum caused a significant decrease in leafhoppers. There was an interaction between pyrethrum and cuprous oxide in leafhopper control. Cuprous oxide in the absence of pyrethrum also caused a decrease in leafhoppers but where these materials were used together the control was no better than with either material alone. The yield paralleled the leafhopper control in these cases.

Rotenone reduced the numbers of flea beetles and aphids which might have been sufficient to account for the increased yields obtained with this material. There appears to be nothing in the insect control record to account for the significant interaction between rotenone and pyrethrum in influencing yields. The use of either material alone increased yields as much as both together in this experiment but it is

likely that this may not always be the case as they seem to control different insects.

Sulfur gave the best control of leafhoppers of any of the materials used and also was the only material to cause a significant reduction in tarnished plant bugs. The lack of any significant increased yields from the use of this material would, therefore, be surprising if this did not correspond with some previous experience. The results so far with this material seem to indicate that its beneficial effects by insect control only over-balance its harmful effect on the plants if the insects to be controlled are fairly numerous. Perhaps it should only be applied at the peak of infestations rather than throughout the year.

The red cuprous oxide, aside from the above-mentioned control on leafhopper in the absence of pyrethrum, resulted in significant decreases in flea beetles and aphids. It may be said that in another factorial experiment in the same section cuprous oxide gave reduced counts of aphids but that this decrease was not statistically significant. It does seem likely that the control of leafhoppers in the absence of pyrethrum, the control of flea beetles and the reduction of aphids may have caused the increased yields. The near significant interaction between pyrethrum and cuprous oxide in influence on yields which corresponds with the significant interaction in leafhopper control points to its influence on leafhoppers as important.

In no case did the addition of cuprous oxide impair the value of the insecticides used in this experiment. Though both rotenone and cuprous oxide significantly reduced flea beetles, their effects appear to have been independent and additive. Pyrethrum and cuprous oxide used together gave results on leafhoppers that were not significantly different from those of either material used separately and the same may be said for rotenone and cuprous oxide with respect to aphids. It appears then that cuprous oxide may be added for its fungicidal value, which could not be determined in this experiment, not only without impairing the efficiency of the insecticides used in this test but in some cases supplementing them.

In the experiments on irrigated plots a pyrethrum sulfur dust and a pyrethrum, rotenone, sulfur dust both gave increases in yields comparable with those obtained in the factorial experiment with the better mixtures.

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POTATO CONSUMPTION AND DIETETIC VALUE IN 1938 AND 1939

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The report of this committee consists of a review of some of the recent literature on disposition and various uses of potatoes, consumer preferences, composition and dietetic value of potatoes. Chemical abstracts provided much of the material used in this report.

Disposition of the Crop

Motts (31) found that from the 1924 to 1935 seasons an average of 55 per cent of the Michigan crop was sold by growers; 20 used in their homes; 15 kept for seed, and the remaining 10 per cent fed to livestock or wasted.

Park of the Bureau of Agricultural Economics, U. S. D. A. commenting on the utilization of four crops 1932-'35 in 30 late states estimates that 30 per cent was shipped in carlots or by boat; 35 was available for market by motor truck or in small lots; 16 saved for food on farms where grown; 11 saved for seed in the locality where grown, and 8 per cent was unfit for food or seed. There are 18 starch factories in Maine and Park states that in years of large crops and low prices the quantity used for making starch has exceeded 5,000,000 bushels whereas in years of high prices the quantity used has often been less than 1,000,000 bushels. He also states that losses in farm storage often range roughly from 5 to 20 per cent and sometimes higher. Merchantable stocks in recent years have varied from 0.6 bushel to approximately one bushel *per capita*.

Market Preferences

The market preferences of Detroit consumers as determined by Motts (31) appear to be for potatoes of medium size (2½ inch diameter) and oval shape. Two persons preferred white skin to one favoring a russet skin. The hotel and restaurant trades prefer a somewhat larger tuber (3 to 3¼ inch diameter) but the preference for an oval shape is less marked, but the preference for white skin varieties was in the same ratio as that of the housewives. Regarding cooking

qualities, there is a desire by all users for potatoes that bake, boil and fry white and retain their color for about an hour after cooking. A dry mealy texture is preferred when the potatoes are baked, and the tubers should be free from lumps and uniform in texture when cooked.

Hardenburg (17) in a study of samples of potatoes purchased in retail stores in Cleveland and Rochester found that they averaged 6.11 per cent damage and 2.21 per cent serious damage from tuber bruising. This represented 38.6 per cent of the total damage from all causes. Fifty-eight samples analyzed at the car and later in the retail market showed an increase of more than three-fold in total bruising damage from handling, the final total percentage by weight being 12.69 per cent.

Garey (14) in a study of consumer demand in Minneapolis and St. Paul found that there are two outstanding requirements on the part of consumers for potatoes, uniformity in size and satisfactory cooking qualities. He also pointed out that they demand potatoes free from disease.

Whiteman and King (50) found that the amount of waste in preparing and cooking potatoes varied with the cooking method. They found that in potatoes baked, peeled and riced the loss was 24.4 per cent; boiled in the skin, peeled and riced the loss was 8.5 per cent; boiled in the skin, peeled and diced the loss was 6.6 per cent and pared, boiled and riced the loss was 14.2 per cent.

Composition

The increase in sugar content in potatoes stored at 7.5°C. is again reported by Barker. He also observes that there is no clear relation between culinary quality and sugar content. Tyrosine is responsible for only a fifth of the observed reducing power of the substances in potatoes is reported by Isherwood (20).

Horner (18) studied the changes in mineral content of potatoes. Potatoes were blanched in water (5 min. at 212° F.) containing CaO, 0.009 and MgO, 0.0024 per cent and having a permanent hardness of 1.1 and total hardness of 11.0 degrees. The loss of potassium and phosphorus was 9 per cent each and the loss of magnesium was 25 per cent. All potatoes showed some gain in calcium.

Schaible, Bandemer and Davidson (37) found the manganese content of potatoes to be 2.9 parts per million, but this content varied according to the conditions under which the crop was grown. Tubers grown on highly acid soils contained more manganese than those grown on less acid or on alkaline soils.

Stevenson (44) found that the German variety, Parnassia, which has been reported to produce 18 to 20 per cent starch under European conditions, contained only 11.7 to 14.7 per cent (average 13.5 per cent) when grown under Maine conditions. It did not differ significantly from Green Mountain.

Bewell (5) of the Canadian Department of Agriculture pointed out that good cooking quality was associated with high dry matter in potatoes. Potatoes below 20 per cent dry matter are of poor quality, between 20 and 22 per cent fair quality; between 22 and 25 good quality, and above 25 per cent excellent quality. He also found that there was a high correlation between dry matter content and the specific gravity of the potatoes and has developed a lyrometer from which the approximate dry matter content of any lot of tubers may be read directly. An effort is being made to assure the purchaser with regard to cooking quality as well as to grade with the hope of stimulating consumption.

Ashkins and Zwemer (1) classified foods in six groups according to their potassium content and arranged diets ranging from low to high in potassium. Potatoes are in group 5 ranging from 0.4 to 0.5 per cent potassium along with fish, red meats, barley, (whole grain) flour, (graham, rye) rye, wheat (whole grain) and bananas. Potatoes are included in all the recommended diets once or twice a day except in the lowest containing only one grain of potassium per day.

The melanin number and the autolytic value of various types of potatoes should prove a valuable guide in selecting varieties which will give the least discoloration in the product according to Haehn (15).

Metzger, *et al* (28) found that the same variety of potatoes from one locality may differ significantly in starch, dry matter, protein and ash from that of another locality. Varieties may differ significantly in the same constituents. A significant difference in dry matter, protein and ash between years was also obtained. Irrigated potatoes are higher in starch and dry matter but lower in protein than dry land potatoes.

Davidson and LeClerc (10) found that all cereals tested and standard wheat bread had an acid balance while potatoes have a distinct alkaline ash and a distinct base balance. They also suggested that the significance of the acid base balance, if any, besides its possible contribution to the acid base equilibrium of the animal or human system, may lie also in its effect on the end products of mineral metabolism.

Molchanova (30) found that when foods high in acidic constituents (meat and cereals) were used at high altitudes the acid base equivalent was shifted toward acidosis with a low positive N balance and a negative P balance. When foods high in alkaline constituents (pota-

toes, cabbage, beets, tomatoes, etc.) were used the urinary N became normal, the coefficient of assimilation of proteins was increased, a positive P balance and higher N balance were obtained.

USES

Bowen (8) describes the manufacture of a product from potatoes having yeast-activating and flour-improving properties. The product is prepared by mixing 7 parts of boiled or steamed potatoes with one part of a salt mixture made by mixing 62 parts of mono-calcium phosphate, 10 of calcium sulphate, 8 of ammonium chloride and 20 parts sodium chloride. The salt mixture is dissolved in a small quantity of water before mixing with the cooked potato. The mixture is then subjected to an elevated temperature to, at least, partly dextrinize the starch after which the product is dried.

Trognitz (47) added potato flour prepared as dry meal from the cooked potato and potato starch prepared from the raw potato singly and as a mixture of equal parts, to wheat flour. He concludes that small additions (3-4 per cent) act favorably on the baking quality of wheat flour. Higher additions are to be avoided since they have a detrimental effect on appearance, crumb quality, odor and flavor.

More than 6,500,000 bushels of potatoes were diverted from trade channels by the Potato Diversion Program of 1937-1938. All these potatoes were U. S. No. 2 grade or better. This figure does not include potatoes diverted to starch factories in Maine, or to a large quantity of culls which were diverted because the interstate movement of culls was prohibited by the agreement.

Morrison and Turk of the New York State College of Agriculture point out that dairy cows can consume 24 to 40 pounds to the head daily. Swine can be fed all of the cooked potatoes they will clean up when they are full fed on corn, barley or other grain supplemented with a protein-rich mixture. Potatoes can satisfactorily replace corn silage in beef cattle rations. Sheep may be fed 2½ pounds of potatoes daily for each 100 pounds live weight. Horses may be fed three to five pounds daily. Much of this same information has been included by Metzger (29) in the information to potato growers from the Colorado Experiment Station.

The manufacture of potato meal in Idaho is another new feature affecting the consumption of potatoes. This product differs from starch in that all the dry matter of the potato is included. Other recent developments pertaining to the consumption of potatoes include the adver-

tising campaigns of Maine, Idaho, and the National Potato Institute; the first annual national potato week; and the recent announcement of the establishment of four new regional laboratories by the U. S. D. A. for research on the utilization of farm products,—among which potatoes are included. This committee wishes to call attention to a matter concerning consumption which was brought up at the annual meeting of the Northwest Potato Association. Attention was called to the number of times potatoes were mentioned in retail grocery store advertisements in the daily papers. Irish potatoes were not mentioned in any of the ads of the current issue of the leading newspaper of that city and the writer has looked in many papers since and found that Irish potatoes are very seldom quoted in these advertisements. Even during national potato week they were only occasionally quoted.

Fink (12) proposes to make 40,000 to 100,000 tons of crude protein annually from potatoes since 700,000 tons must be imported into Germany.

Kroner (22) discusses potato storage, preparation of dried food and fodder products, preparation of starch syrup, starch sugar and pure glucose, and the use of waste water from starch factories as a source of protein in Germany.

Duddy and Reozan (11) estimate the pounds *per capita* supply of potatoes in the United States by five-year periods allowing 20 per cent for seed and waste as follows:

1866-1870	150.3	1906-1910	184.8
1871-1875	161.1	1911-1915	174.3
1876-1880	156.4	1916-1920	155.8
1881-1885	171.9	1921-1925	153.9
1886-1890	158.6	1926-1930	143.4
1891-1895	166.8	1931	144.6
1896-1900	161.0	1932	137.4
1901-1905	170.7	1933	122.8

These authors also point out the reasons for the decline in consumption. The proportion of the population living in cities increased from 46.3 per cent in 1910 to 52.2 per cent in 1930. High land values in the cities crowded out the single family dwelling, modified the size of family, style of living, food buying and storage habits. Better heating of buildings lessened the demand for heavy foods high in calories. The increase in mechanical power lessened the muscular energy required of the laborer. There was also a decrease in the length of the working

day. The proportion of the population engaged in trade, commerce, professional work, and clerical work almost doubled from 1880 to 1930. These changes required less muscular energy and less of the energy-producing foods. Women require 300 to 500 calories per day more than men and men engaged in sedentary work only require 2,100 to 2,500 calories while in severe muscular work they require 4,500 to 6,000 calories.

Mangold (26) determined the biological value of various potato protein flakes on hogs by metabolism and found it to be 84 per cent. Similar experiments on poultry gave considerably lower results (60 per cent).

VITAMINS

Lyons and Fellers (24) and Paech (33) found that the highest concentration of ascorbic acid was in the central portions of the tuber and the lowest next to the skin. Lyons and Fellers also concluded that variations in ascorbic acid content of potatoes of different sizes and from different geographical sources were not particularly significant. Cooking in salted water preserved more ascorbic acid than when the potatoes were cooked in unsalted water, and the salted material retained its ascorbic acid better when mashed. The cooked potatoes contained 0.061 to 0.165 mg. ascorbic acid per gram and were considered good sources of vitamin C.

Either baking or boiling caused approximately 40 per cent decrease in ascorbic acid content, and a further decrease occurred in boiled potatoes that were held at 40° F. for 24 hours. Similar observations were made by Janse-Stuart (21).

Illyuviev (19) reports that nitrogen and potassium fertilizers increase the vitamin content of potatoes.

Wachholder and Nehring (48) conclude that the content of vitamin C is largely a varietal characteristic, one sort may have twice as much as another and in different years the rank is about the same. They also report on the loss in vitamin C content during cooking and storage.

Woods (51) maintained rats on a vitamin G free diet by feeding four grams of potatoes daily for four weeks.

Richardson, Davis, and Mayfield of the Montana station studied the vitamin C content of potatoes after they were cooked by different methods using two varieties. They found that boiling or washing had little effect on the vitamin C content; steaming increased it slightly; baking produced a definite increase, pressure cooker produced a slight loss, American fried in butter produced a loss of nearly one-half and

escalloped retained all the vitamin C but it was diluted by the milk used. Raw Russet Burbank tubers contained 0.126 mgs. per gm. whereas raw Bliss Triumph contained 0.133 mgs. per gm. and this relationship was maintained in the cooked product. These figures are equal to those of the poorer varieties of tomatoes according to determinations by Maclinn, Fellers, and Buck (25).

Mayfield *et al* (27) found that in the fall 1.3 gms. of either raw or cooked Russet Burbank potato contained one Sherman unit of vitamin B. After six months storage there appeared to be no loss in raw potato, but when cooked there were indications of a 19 per cent loss. In the fall both animal and chemical tests for vitamin C indicated that 4.5 gms. of raw Russet Burbank contained one Sherman unit. Cooking caused practically no loss. Six months storage caused no loss in the raw potato according to animal tests but a 33 per cent loss determined chemically. When these potatoes were cooked both tests showed a loss of 45 per cent. Raw Bliss Triumph lost one-third to one-half of its vitamin C after 6 months storage and 55 per cent when cooked. After two months storage the potatoes contained about two-thirds as much vitamin C as in the fall.

Scheunert (38) found that different fertilizer treatments produced no significant variations in the vitamin content of potatoes.

Smith and Patterson (41) determined the ascorbic acid content of different lots of potatoes and concluded that the value obtained was affected by the variety, the freedom of stock from virus disease and the duration of storage.

Smith and Patterson (42) used a modified indophenol method for determining ascorbic acid in the rapid, routine examination of potato tubers. The results showed definite and characteristic differences for different varieties of healthy potatoes. The results are independent of tuber size, are not affected by the locality in which the tubers are grown, the fertilizer treatment, or soil pH. The ascorbic acid content of tubers decreases more rapidly at room temperature than in cold storage. Tubers from plants affected with mild or severe mosaic or leaf-roll gave higher indophenol values, whereas those from blighted plants gave lower values.

Thornton (45) exposed newly harvested Green Mountain tubers to 30 to 60 per cent of CO_2 at 25 degrees C for various periods. They contained 25 mgms. of ascorbic acid per 100 gms. of tissue before treatment. The treatment caused a reduction of 16 to 40 per cent. A reduction of 8 per cent was obtained by the CO_2 accumulating from res-

piration. The CO_2 had no detectable effect on the ascorbic acid content of the tubers 150 days after harvest.

Fitzgerald and Fellers (13) point out that potatoes contain 50 I. U. per 100 gms. of carotene whereas onions and beets contain none and kale contains 45,000 I. U. per 100 gms.

Blagoveshchenskii (7) grew potatoes at altitudes of 2,300, 3,650, and 4,000 m. above sea level. The ascorbic acid content markedly increased with the increase in altitude.

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THE INFLUENCE OF A 3-YEAR ROTATION AND FERTILIZER TREATMENTS ON THE ORGANIC CARBON OF SOILS*

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The organic carbon level of soils and its turnover are important in the growth of crops. The carbon level is also one of the controlling factors of soil tilth and of accelerated erosion. The effects of various fertilizer treatments and a 3-year rotation are presented with general observations concerning erosion.

We are giving here some brief statements from some of the existing literature pertaining to soil nitrogen and organic carbon. Reference is given to those experiments which compare yield or soil data of manured, limed and chemically fertilized plots, the effect of organic carbon on infiltration, and experiments including potatoes as one of the crops in a rotation.

Thorne (10) has reviewed the research work dealing with manure and chemicals of the long-time experiments at Rothamsted, Pennsylvania, Ohio, Missouri and Indiana stations. The literature reviewed and the data presented by Dr. Thorne show that yields may be maintained as successfully by chemical fertilizers as by manure for ordinary farm crops. No attempt is made to disprove the value of manure. Blair (1) presents similar data showing that gains in soil nitrogen and organic carbon are made at the expense of large losses.

Turk and Millar (11) concluded that the nitrogen content of a soil

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depends on climate and cropping system with emphasis on biological activity and organic matter turnover. Certain crops may demand a uniform water supply which a high organic matter level helps to maintain. Lime increased organic matter decomposition but increased crop residues sufficiently to balance this loss. A high correlation coefficient was found when differences in organic matter were correlated with differences in water holding capacity. Stauffer (9) found 1.70 per cent organic carbon in plots cropped to corn; 2.20 per cent in plots cropped to corn when fertilized, and 2.90 per cent in a fertilized rotation of corn, oats and red clover. The water holding capacity varied from 56 per cent by weight for the soil continuously cropped with corn to 75 per cent for the fertilized rotation.

Bushnell (3) showed that corn gave larger amounts of organic matter to plow under than either sweet clover or soybeans as green manure crops. All potato yields have been highest after corn. Additional nitrogen was supplied to compensate for adding large amounts of organic matter low in this element. Smith (8) has outlined an extensive experiment using green manure crops to increase potato yields and has given preliminary data showing highest organic matter yields from corn and sunflowers.

Salter and Green (7) compared the effects of continuous corn, wheat and oats and 3-year and 5-year rotations on the nitrogen and organic carbon level in the soil. In the 3-year rotation of corn, wheat and clover the accumulative effect of the clover crop on the limed but otherwise untreated soil approximately balanced the destructive effect of the corn crop. Residues of the corn crop were of little value in conserving soil nitrogen or organic carbon; those from oats were notably effective; and those from wheat intermediate in value.

Odland (6) reported that during a 40-year period yields of potatoes have averaged about the same for five different rotations including three, four, five and six-year rotations with legume and non-legume hays, corn and rye. In a five-year study of continuous culture *versus* rotation for potatoes, Brown (2) obtained results favorable for the rotation during the two dry years of the experiment and an index of 109 for the potatoes in the rotation as compared with 100 for potatoes continuously. Chucka and Lovejoy (4) obtained increases in potato yields when green manures and farmyard manure were utilized in addition to regular commercial fertilizers. An increase of 156 bushels resulted from the addition of one green manure crop and 20 tons of manure per acre. Other tests showed very marked yield increases from

TABLE 1—*Fertilizer treatments and organic carbon in pounds per acre at the beginning and end of 6-year period with odds for significance*

Treatment	1932 O. C. in lbs.	1936	Difference lbs.	Odds
No fertilizer	52,600	50,600	—2000	18-1
4-8-7 Check	52,600	50,600	—2000	1-1
4-8-7 + L	56,000	58,400	+2400	50-1
4-8-7 + LL	54,200	55,800	+1600	7-1
4-16-7	51,000	49,400	—1600	2-1
4-0-7	55,200	50,800	—4400	33-1
8-8-7	51,800	51,600	— 200	1-1
0-8-7	51,400	50,000	—1400	500-1
4-8-0	48,400	47,200	—1200	3-1
4-8-14	52,000	49,400	—2600	4-1
4-8-7 in bands	54,600	50,800	—3800	10,000-1
8-16-14 (1000 lbs.)	53,600	51,600	—2000	10-1
4-8-7 No Mg.	56,400	54,000	—2400	10,000-1

manure. These increased yields were believed to result mainly from the beneficial effect of the organic matter.

Metzger (5) concluded that, in general, manure and green-manure-treated plots maintained higher soil nitrogen and carbon levels than control plots. Commercial fertilizers tended to produce similar results, but they were much less marked. Numerous other data and conclusions of particular significance are presented in the bulletin.

EXPERIMENTAL METHODS

A 3-year rotation of potatoes, oats and clover was followed. The oats and clover were removed as hay. Fertilizer and lime treatments on the Lane farm included the following formulas: 4-8-7 plus single lime, 4-8-7 plus double lime, 4-8-7 check, 0-8-7, 8-8-7, 4-0-7, 4-16-7, 4-8-0, 4-8-14, 4-8-7 in bands, 8-16-14, 4-8-7 no magnesium, and no fertilizer.

All treatments were applied to the potato and on the basis of 1 ton of 20-unit fertilizer per acre. Single lime applications were made at the rate of 4000 pounds of calcium carbonate per acre applied to the oats.

Fertilizer treatments on the Jackson farm included 4-16-7, 4-8-10 for 6 years and 4-8-14 for 6 years, 4-8-7 check, 4-8-7 plus lime, 4-8-0 plus lime all applied in amounts similar to the above-mentioned amounts. One additional treatment consisted of 3000 pounds of 4-8-7 during 6 years and the same unit quantity from Ammo Phos A and Nitrate of Potash during the latter 6 years of the experiment.

Jackson Farm Results

Table 2—*Fertilizer treatments and organic carbon in pounds per acre at the beginning and end of 12-year period with odds for significance*

Treatment	1927	1939	Difference	Odds
4-8-7 Check	75,000	65,000	—9400	→ 100-1
4-8-7 (3000#)	79,600	68,000	—11,600	→ 100-1
4-8-10, 6 yrs.; 4-8-14, 6 yrs.	74,800	65,600	—9800	→ 100-1
4-16-7	69,600	66,600	—7400	→ 100-1
4-8-0 + L	72,600	65,200	—5400	→ 100-1
4-8-7 + L	72,000	66,600	—3000	→ 100-1

Each plot was sampled to plow depth at the beginning of the experiment. The samples were air-dried and sealed in mason jars. At the end of two rotations on the Lane farm and four rotations on the Jackson farm the fields were again completely sampled and organic carbon analyses were made of all samples. All samples were pulverized to pass a 100-mesh screen and analyzed by the dry combustion method.

The soil type on the Lane farm was Paxton loam. The surface soil at this farm to a depth of 6 to 7 inches is a dark brown loam. The subsoil, to a depth of 14 or 15 inches, is a yellowish-brown friable loam. A greenish-yellow moderately gritty loam extends from the 15-inch level to a depth of 18 inches. At 18 to 20 inches this type passes into greenish-gray fairly gritty schist till, which is very compact and has a platy structure. Parent material consists of a mixture of schist, gneiss and coarse crystalline rocks.

The soil type on the Jackson farm was Worthington loam. This soil consists of a brown to dark brown surface soil six to seven inches deep. The subsoil, to a depth of about 12 inches, is a yellowish-brown loam. This is underlain by 2 to 3 inches of greenish yellow loams which passes into greenish gray firm but friable till. It is developed from schist till that has some calciferous or limey schist and siliceous limestone incorporated in the material. Both Paxton loam and Worthington loam are acid throughout.

Discussion of Results

The losses of organic carbon from the check plots on the Lane farm were not statistically significant. However, several other treatments of similar nature gave significant or nearly significant results for similar

TABLE 3—*Fertilizer treatments and per cent and average yearly increase or decrease in organic carbon*

Treatment	Per cent Increase or Decrease in O. C.	Yearly Average
	Lane Farm — 6 Yrs.	
No fertilizer	—3.80	—0.63
4-8-7 Check	—3.80	—0.63
4-8-7 + L	+4.29	+0.72
4-8-7 + LL	+2.95	+0.49
4-16-7	—3.14	—0.52
4-0-7	—7.99	—1.33
8-8-7	—0.39	—0.06
0-8-7	—2.73	—0.46
4-8-0	—2.48	—0.41
4-8-14	—5.00	—0.83
4-8-7 in bands	—6.96	—1.16
8-16-14 (1000#)	—3.73	—0.62
4-8-7 No Mg.	—4.56	—0.76
	Jackson Farm — 12 Yrs.	
4-8-7	—12.5	—1.04
4-8-7 (3000#)	—14.6	—1.22
4-8-10 (6 yrs.) } 4-8-14 (6 yrs.) }	—13.1	—1.09
4-16-7	— 4.3	—0.36
4-8-0 + L	—10.2	—0.85
4-8-7 + L	—10.3	—0.86

decreases. These included the one-half ton 8-16-14 application and the 4-8-7 no-magnesium application. Little, if any, benefit in crop yields was derived from the magnesium. These three treatments gave total losses of 2000, 2100, and 2400 pounds of organic carbon per acre for the six-year period. These values represent losses of 0.63, 0.62, and 0.76 per cent per year.

The organic carbon losses were great when the fertilizer was applied in bands in the row. No particular reason was evident from the yield data to account for this large loss.

The fertilizer applications plus lime and double lime showed additions to the organic matter level.

In order of increasing phosphorus applications the data showed decreasing loss of carbon. Organic carbon losses increased when applications of potassium were increased although the results obtained were not statistically significant. Applications of 4-8-7 fertilizer resulted in higher losses than either the 0-8-7 or the 8-8-7.

Accelerated soil erosion had become noticeable on the area. This erosion was in the form of sheet removal with the formation of rills on some sections of the field.

The best yield of potatoes, 269 bushels per acre, was obtained from the double strength fertilizer treatment. The check plots yielded 239 bushels per acre.

Results on the Jackson farm gave approximately the same losses for the 4-8-7 check, 4-8-7 (3000 pounds per acre) and the 4-8-10 = 4-8-14 combination. Organic carbon losses were materially decreased with the high phosphorus application. It should be noted that the organic carbon levels in the plots having this treatment were lowest at the beginning of the experiment in 1927. The organic carbon level in 1939 was not so low as in some other treatments. The use of lime reduced organic carbon loss from 22 to 42 per cent.

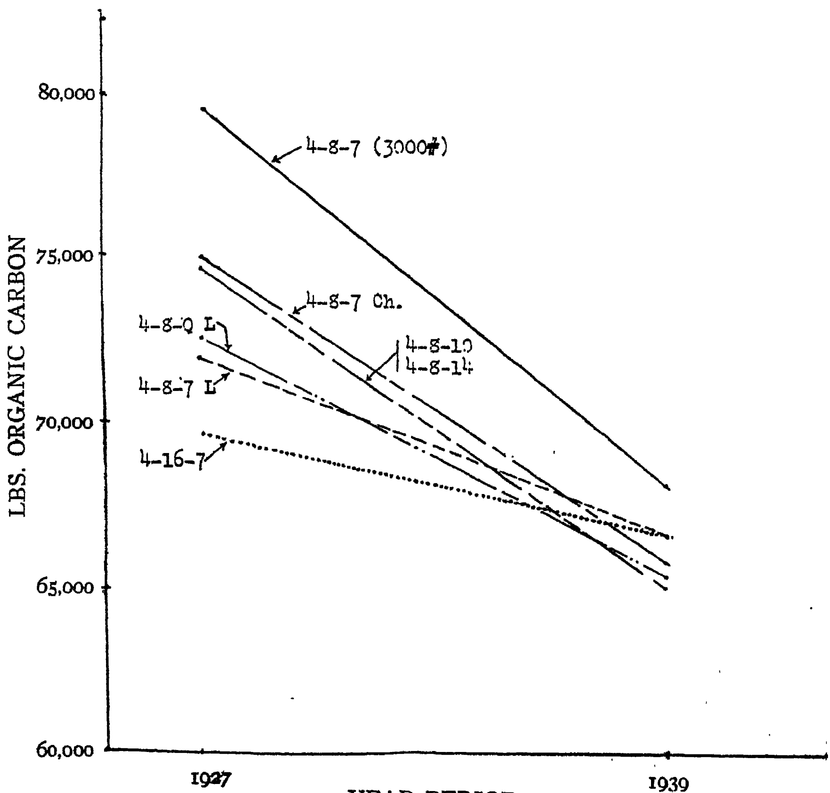

FIGURE 1.—Organic carbon in pounds per acre at beginning and end of 12-year period, Jackson Farm.

Figure I shows the tendency of the organic carbon level to approach a value caused by all environmental factors including the 3-year rotation, cultivation, and varied fertilization as conditioned by the climate. Several fertilizer treatments were significantly more effective than others in maintaining the organic carbon level. Because of the tendency for all treatments to approach the same relative organic carbon level the kind of rotation and amount of cultivation are considered particularly important.

The check plots yielded an average of 378 bushels of potatoes per acre. Of the treatments analyzed the highest yield, 414 bushels per acre, was obtained from the 4-16-7 treatment.

Summary

The effects of a 3-year rotation and fertilizer treatments on the organic carbon of soils have been presented. The rotations consisted of potatoes, oats and clover. Basic fertilizer treatment was a one-ton per acre application of 4-8-7. Ohter treatments included variations in amounts of nitrogen, phosphorus, potassium and lime applied.

The following conclusions were made:

1. Organic carbon losses must be expected when potatoes are raised in a 3-year rotation with oats and clover with the removal of all crops.
2. Of the various fertilizer and lime treatments analyzed additions of lime and formulas high in phosphoric acid gave best results in reducing organic carbon losses.
3. The 4-8-7 plus lime treatment was not so effective as the 4-16-7 treatment in producing high yields but it was more effective in maintaining the organic carbon level.

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RESULTS OF EXPERIMENTS IN CONTROL OF BACTERIAL RING ROT OF POTATOES IN 1940

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Ring rot was first recognized in this country in 1934, but it did not cause any serious concern until 1937 and 1938 when it caused serious damage in many potato-growing states. On account of the rapid spread and the destructiveness of ring rot wherever it appeared, the disease became a source of great concern among potato growers, especially since definite information on the behavior of this disease and its control was lacking.

In order to make an effort at some organized attempt to learn more about the nature of this disease and means of combating it, a national symposium on ring rot, sponsored by the Potato Association of America, was held during the meetings at Richmond, Virginia, during the winter of 1938. This session was attended by representatives from approximately 30 states and included both research and extension workers, as well as seed certification officials.

As a result of this meeting a committee was appointed consisting of J. G. Leach of the University of West Virginia, R. W. Goss of the University of Nebraska, and T. P. Dykstra of the U. S. Department of Agriculture for the purpose of stimulating and co-

[1]Pathologist. Data furnished by investigators in different states.

ordinating research on ring rot. The Committee felt that its first function should be to make a survey to determine the extent of the occurrence of this disease in the United States.

A complete report of this survey was made at the Columbus meeting in 1939 by the chairman of the Committee, J. G. Leach, and was later published in the American Potato Journal, (1). This survey revealed that ring rot was present in at least 27 states and served to confirm earlier expectations that the disease would prove to be very destructive.

On the basis of the survey of 1940, the committee submits the following report:

Ring rot has now been definitely reported from 37 states in 9 of which it was first reported this year. Of the 28 states reporting the disease in 1939, 14 reported it to have increased in prevalence and severity. Eight reported less in 1940 than in 1939. One state reported no change; and no reports were received from the remaining 5 states. Fifteen states reported that definite results had been obtained where control measures were used. All agreed that the use of certified seed *showed satisfactory results,* but several seed-producing states pointed out that the disease continued to show up in some lots of certified seed and that methods now available for enforcing a zero tolerance were not effective.

The difficulty of accurate diagnosis, either in the field or from lightly infected tubers, was emphasized by many workers. Although the outlook for control in certified seed was fairly good, many expressed the opinion that the problem of control by the producers of table stock would be much more difficult. Several reported evidence that the appearance of the disease in fields grown from certified seed is not proof of laxity in certification, for there are many other sources of infection. Caution should be used in attributing infection to any one source on the basis of circumstantial evidence.

It is evident from the letters received by the Committee that ring rot is rapidly becoming one of the most destructive diseases of the potato in this country. Although we have not yet had enough time to test adequately the present recommended control measures, it is generally agreed that the disease is very likely to become more destructive before it is brought under reasonable control. The imperative necessity for both extensive and intensive research has been emphasized by all collaborators.

The committee to coordinate research on new and unusual potato diseases consists of J. C. Leach, *Chairman;* R. W. Goss and T. P. Dykstra.

Because of the critical nature of the problems raised by the presence of this disease, an experimental basis for control is urgently needed. Since the prevalence of the disease is nationwide it should be investigated in as many parts of the country as possible, and the information secured should be readily made available to any one interested in this problem. Since the National Potato Project of the United States Department of Agriculture has the facilities to coordinate such a program, the Committee feels that this is the logical agency for this service, and has assigned the function of coordinating research on ring rot to this project.

The Committee will continue to serve in an advisory capacity and will aid in the exchange of information or do anything else to further an adequate program of research.

Several states which are investigating the ring rot disease of potato have agreed to take part in this nation-wide program and have submitted reports showing the results obtained in their investigations. Cooperating states and investigators submitting reports are as follows: Alabama, H. Darling; California, J. B. Kendrick and C. E. Scott; Colorado, D. P. Glick and W. A. Kreutzer; Florida, A. H. Eddins; Idaho, J. M. Reader; Kansas, O. H. Elmer; Maine, R. Bonde; Minnesota, C. J. Eide and R. B. Harvey; Montana, F. M. Harrington; New Jersey, R. H. Daines; North Dakota, W. E. Brentzel; Oregon, C. E. Owens; West Virginia, J. G. Leach; Wyoming, G. H. Starr and W. A. Riedl; U. S. Department of Agriculture, L. Cash.

Transmission of ring rot by cutting knife.

The fact that ring rot is readily transmitted by a seed cutting knife that previously had been used to cut infected tubers has been abundantly demonstrated by experiments in Oregon, California, Florida, Minnesota, Wyoming, Colorado and Maine.

Experiments in California showed that the cutting knife was the most effective agent in the spread of bacterial ring rot. Five tests made by cutting healthy potatoes after cutting diseased potatoes (alternate cuts) showed 78, 65, 90, 55 and 56 per cent diseased hills respectively, or an average of 69 per cent.

In order to test the knife as a carrying agent, potatoes were cut in a series after contaminating the knife by cutting a diseased potato. That is, a diseased potato was cut and then a series of 10, 20, or 25 healthy potatoes were cut before the knife was again contaminated. In one test, 11 lots of 25 tubers each were cut in a series with a contaminated knife and planted as tuber units 1 to 25

(4 seed pieces per unit). Diseased units occurred promiscuously throughout the lots.

One lot showed ring rot in the 24th tuber unit; two lots in the 23d unit; and three in the 22d unit. None of the lots showed ring rot in the 25th unit. Of the total of 268 tuber units surviving, 99 showed ring rot or 37 per cent. The various tuber-unit trials in California demonstrated that after a knife once becomes contaminated, the ring rot organism may be carried as far as the 24th succeeding healthy potato and that one slightly diseased potato in 25 might result in 90 to 100 per cent diseased hills.

In experiments in Wyoming the cutting knife was infected by drawing it through an infected tuber and then used to cut 25 healthy tubers. These seed pieces were then planted in the order in which they were cut. This experiment was replicated eight times. The results showed that ring rot was distributed intermittently throughout the 25 units in the row. The four seed pieces from the same tuber did not always show ring rot, although all four pieces came in contact with the same blade.

Transmission by contact of diseased end healthy seed pieces.

That ring rot is readily transmitted by contact of diseased and healthy seed pieces was demonstrated in an experiment in California. Healthy and naturally infected potatoes were cut in separate lots and mixed in the proportion of 1 diseased to 20 healthy seed pieces. The diseased seed pieces were marked. After being shaken up in a burlap bag and left standing for 24 hours, the diseased seed pieces were removed and the healthy seed pieces planted. Of the 200 hills grown from this seed, 138 or 69 per cent showed ring rot.

Spread by surface contamination of whole seed.

In a trial in California, whole tubers were dipped momentarily in a suspension made by grinding diseased potatoes and mixing the pulp in water. The potatoes were planted by hand without cutting. Ring rot developed in 33 per cent of the 132 hills. This shows the danger of surface contamination from soft diseased potatoes in a sack or storage bin. It also shows that wounding or cutting the sound potato is not necessary for the spread of ring rot from diseased to healthy potatoes.

In Oregon, infection failed to develop when material from the vascular ring of ring rot potatoes was smeared on uncut seed potatoes both at the eyes and between the eyes. Severe infection was obtained in plants growing from seed tubers which were inoculated

at the eyes and between the eyes with a needle bearing infectious material from the vascular ring of a ring rot tuber.

Experiments in Wyoming showed that when the eyes of the tubers were rubbed with a portion of an infected tuber, 33 per cent of the plants growing from such tubers were infected.

Infecting tubers by using bacteria taken from artificial media.

Results in Oregon showed that bacteria taken directly from the vascular tissue of infected tubers appeared to be a more reliable source of infection than *Phytomonas sepedonica* cultured on artificial media. Ring rot was transmitted to stems and tubers of potato plants by inoculating the bases of the stems with material from the vascular ring of a ring rot tuber. No infection was obtained using a three-day old culture of *Phytomonas sepedonica* from an agar slope. It was possible to grow infected plants (growing from seed tubers) when the seed tubers were inoculated at the eyes and between the eyes by puncturing with a needle bearing cells of *Phytomonas sepedonica* from agar slope cultures. Infection, however, was rather mild.

Workers in West Virginia tried to produce the disease in the field during the summer, using a number of strains of the pathogen, grown in artificial media. Several methods of inoculation were used, including that of cutting the tubers while submerged in a concentrated suspension of the pathogen. Not a single case of ring rot was produced.

In California, no particular difficulty was experienced in securing infection by using the ring rot organism grown in sterilized broth, according to standard bacteriological methods. Seed potatoes were dipped in these cultures after they were slightly diluted.

At Beltsville, a series of stalk inoculations was made on plants 8 to 10 inches high. Inoculations were made 3 inches above ground with 5-day beef agar cultures at pH 7. Burkholder's special medium for growing *P. sepedonica* was used, and a medium developed by A. E. Quirk of the Department of Agriculture, the formula for which has not yet been published. Prick inoculations were made by applying a loop of culture to the stem with a platinum loop and pricking through this four times with an inoculating needle into the vascular bundles. For hypodermic inoculations an emulsion was made of bacteria from a 5-day agar slant in 5 cc. sterile tap water. Inoculum of approximately the same degree of turbidity was made from the infected vascular tissue of a naturally diseased tuber.

Considerable infection characteristic of the disease developed on

the leaves and stalks. Two and one-half months after inoculation, gram-stained smears were made from these stalks 2 inches above the surface of the soil. The hypodermic inoculation developed at a slightly higher percentage of infection than the stabs, 90 per cent as compared with 87 for the stabs. A series of tubers were inoculated hypodermically with the same cultures used for stalk inoculations. Two stabs were made close to each eye in a slanting direction with an inoculating needle. The hypodermic needle was then inserted and these channels were filled with bacteria. The tubers were planted immediately. Sixty-eight per cent of the plants growing from tubers inoculated with bacteria grown on artificial media developed ring rot, and 86 per cent of the plants growing from tubers inoculated with the bacteria taken directly from diseased tubers became infected.

TABLE 1.—*Number of infected plants arising from seed pieces infected by P. sepedonica surviving on pieces of burlap sack*

Time Bacteria Were on Sacks	Source of Bacteria Put on Sacks												Non-contaminated Control Sacks					
	Diseased Potato						Pure Culture											
	Sterile Sack Replicate			Non-sterile Sack Replicate			Sterile Sack Replicate			Non-sterile Sack Replicate			Sterile Sack Replicate			Non-sterile Sack Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
1 hour	[1]3	2	2	2	2	2	3	3	–	2	3	2	0	0	0	0	0	0
2 days	3	3	3	1	2	3	3	1	3	3	3	3						
1 week	3	1	3	1	2	2	2	3	2	2	3	2						
4 weeks	2	0	1	–	3	3	2	3	3	1	0	3						
7 weeks	0	0	0	0	0	0	2	0	0	0	0	0						

[1]Each replicate pot contained 3 seedpieces.

It is not clear why in some cases it is difficult to secure infection with the organism growing on artificial media.

Survival of Phytomonas sepedonica on sacks.

Experiments on this problem were conducted in Minnesota when it became apparent that growers might be inoculating clean seed by handling it in second-hand sacks that had previously contained ring rot tubers.

Pieces of burlap potato sacks were contaminated at intervals, both with pure cultures of *P. sepedonica* and with the yellow material scraped from the vascular ring of affected tubers. One-half of the pieces of sack was sterilized before contamination. Each

piece of sack was placed in a pint fruit jar after contamination, the cover was then put on loosely and the jars were stored in a potato cellar at approximately 5° C. Seven weeks after the first pieces were contaminated, three potato seed pieces were laid in a pot partly filled with sterile soil. One of the pieces of contaminated sacking was laid on the seed piece in each pot and sprinkled gently with water. After five days the sacking was removed and the seed pieces covered with sterile soil. There were three replicate pots with sacking treated identically in each case.

Fourteen weeks after planting, a smear was made from the stem of each plant. The tubers were harvested and stored at 5° C. for 21 weeks, when smears were also made from them to confirm findings on the stems. The data are presented in table 1.

From this experiment it is concluded that most of the bacteria died between 4 and 7 weeks after being placed on the sacking. Few of those marked "sterile" remained so after smearing diseased material from tubers on them. All these, as well as the "non-sterile" ones (except those contaminated only 1 hour) were covered with molds when they were placed on the tubers. The sterile sacking on which a pure culture of *P. sepedonica* was placed was not moldy. Even so, the bacteria appeared to have survived on only one of three replicates of the latter.

New, unused, but non-sterilized potato sacks were smeared with diseased tissue from tubers, folded and sealed in paper sacks and then stored under different conditions until planting time. Disease-free, cut seed pieces were shaken thoroughly in the sacks before planting. Some sacks that had contained tubers affected with ring rot were used in the same way. Three replicates were planted in different parts of Minnesota. The results are shown in table 2.

The longest period that bacteria survived in these experiments was 121 days; this on a "naturally" contaminated sack. Low infection after 81-82 days indicates that many of the bacteria had died by then. Short survival in experiment 1 as compared with that in experiment 2 may be the result of storage in jars where the sacking was kept moist for some time after contamination. It is concluded that sacks containing diseased tubers emptied during the winter and subsequently sold and used to carry seed are a dangerous source of infection unless disinfected before using.

In Wyoming an experiment was conducted to see how much spread might be caused by a burlap sack that had been used to store for a period of one month an assorted lot of Triumphs containing ring rot.

This sack was used as a container in which healthy seed were churned about from end to end for approximately ½ minute and then planted. Only 1 per cent ring rot developed in these tubers.

Effectiveness of planter in spreading ring rot.

An experiment was conducted in Minnesota to determine the amount of spread of ring rot by means of the assist-feed and the picker planter. The results showed that the highest amount of spread secured by using a contaminated assist-feed planter was 1.5 per cent.

The picker planter, however, proved to be an effective means of spreading ring rot. A test showed that the picker planter

TABLE 2.—*Percentage of potato plants infected with bacterial ring rot by shaking seed in artificially and naturally contaminated sacks*[1]

Description of Sacks	Place Stored	St. Paul [2]		Glyndon [3]	Crookston [4]	Number of Days Survival before Planting
		Seed Shaken in Dry Sacks	Seed Shaken in Wet Sacks	Seed Shaken in Dry Sacks	Seed Shaken in Dry Sacks	
New, uncontaminated		0.0	0.0	0.0	0.0	...
Contaminated 2-29-40	Refrigerator 1-2° C.	0.0	7.4	0.0	2.29	81-83
Do	Dry, unheated shed	0.0	1.0	3.1	8.33	81-83
Contaminated 5-19-40		18.9	23.1	7.4	9.09	1-3
Contaminated 2-6-40	Dry, unheated shed	...	0.0	...	...	...
Contained ring rot tubers until 1-20-40	do	...	1.0	...	...	121
Do	do	...	0.0	...	...	...
Contained ring rot tubers until 2-16-40	do	...	0.0	...	...	...

[1]These results are subject to revision because some tubers may have been infected which showed no obvious symptoms at digging time. These have been stored for examination in the spring.

[2]Per cent hills infected. Planted May 20.

[3]Per cent by weight of infected tubers in a random sample. Planted May 21. Experiments made by Mr. A. G. Tolaas and Mr. Donald Peet.

[4]Per cent hills infected. Planted May 22. Experiments made by Mr. Robert Nylund, Horticulturist, Northwest Experiment Station, University of Minnesota, Crookston, Minn.

doubles or trebles the original amount of ring rot in a seed lot in spite of precautions to prevent spread in other ways. The effectiveness of an instrument similar to the "picker" on a picker planter was demonstrated in another experiment. Two nails in a block of wood were thrust into a tuber with ring rot. The instrument was then thrust into a number of seed pieces which were planted in the order in which they were injured. At harvest time it was found that seed pieces up to and including the 20th injured after contaminating the picker gave rise to infected plants.

In the California field trials small spikes similar to those in the picker type planter were used first to puncture a diseased potato and then a healthy seed piece or small whole tuber before planting. In one trial of 246 hills from cut seed pieces 158 or 64 per cent showed ring rot. In another trial 62 hills from small whole seed showed 28 diseased hills or 45 per cent. Infection occurred regardless of whether the spike penetrated the cut surface or the skin of the healthy seed piece.

Spread in the field.

In Montana alternate plantings of diseased and healthy seed pieces were made in the field. The results showed that spread occurred only in that portion of the field in which irrigation conditions were poor, where water backed up or did not flow freely in areas where the slope permitted a steady flow of irrigation water. Dissemination did not occur.

In Florida, two rows, each 80 feet in length, were planted with seed from ring-rot-infected stock, and 4 rows on each side of these were planted with seed known to be free from ring rot. The slope of the land was parallel with the length of the rows. A shallow drainage ditch was located across the rows approximately one-seventh of the distance from one end. None of the plants or tubers from the row planted with the disease-free seed showed any symptoms of ring rot, whereas 80 per cent of the plants in the rows planted with seed from the ring rot stock were affected with the disease. One tuber from each of 358 hills located in the 8 rows planted with ring-rot-free seed was saved for planting in 1941 to ascertain if the disease would become evident in 1941 as a result of spread from row to row in 1940 when it did not develop enough to be detected.

In an experiment in Minnesota 100 hills were planted with ring-rot-free seed, excepting every eleventh hill which was planted with a ring-rot seed piece, visibly but not heavily infected. At

harvest time only one of the plants from ring-rot-free seed was infected and this one was midway between two infected hills. Because this was the only plant infected, it is thought that it may have become contaminated from some source other than by spread after planting. None of the plants in the check rows next to infected rows in any of the experimental plots was found infected at harvest time.

Field trials were conducted in California to determine whether or not ring rot spreads from plant to plant under field conditions, by planting diseased and healthy seed pieces alternately in the row. Each hill was carefully dug and examined. In one trial 156 hills from healthy seed pieces dipped in a suspension of a laboratory culture of *Phytomonas sepedonica* showed 47 or 37 per cent disease, whereas among 154 hills grown alternately between the inoculated seed pieces there was only one diseased hill. There was little doubt that this one hill came from an inoculated seed piece and resulted from a misplaced marker as each adjacent hill was healthy.

In another trial, in which naturally diseased seed pieces and healthy seed pieces were planted alternately, 73 per cent diseased hills resulted from the diseased seed pieces, although there was only 3.4 per cent of ring rot from healthy seed pieces grown adjacent to diseased plants. Again, it was quite evident that these two diseased plants resulted from misplacing of markers. A similar test in 1939 showed no evidence of ring rot spreading from diseased to adjacent healthy hills.

In Oregon very slight transmission of ring rot took place between cut ring rot seed pieces and healthy cut seed pieces when planted side by side in the same pot.

Overwintering of Phytomonas sepedonica in the soil.

The ring rot organism failed to overwinter at Fargo, North Dakota, in the soil in which severely diseased potatoes were grown during the preceding year. In 1939 a field was planted with potatoes, 85 per cent of which were infected with ring rot. The potatoes were carefully dug from this plot by removing all the small and large tubers that were sound. A considerable number of rotted and partly rotted tubers were left in the soil. The land was plowed soon after harvest. Healthy Bliss Triumph and Irish Cobbler potatoes were planted on this plot on the 10th of May, 1940. The plants which grew on this land appeared normal, not one showing symptoms of ring rot. When mature, the tubers were carefully examined and found to be free from ring rot.

In another experiment tubers, partially decayed, were mixed

with soil and placed in 10-inch flower pots to overwinter. Each pot received the equivalent of 12 diseased tubers. They were buried to the rim in soil outdoors in November 1939. The control pots received no tubers of any kind. In May 1940, healthy Irish Cobbler potatoes were planted in the pots. One half of a tuber was planted in an inoculated pot and the other half was planted in a control pot. Only one plant developed ring rot. Each tuber was examined separately for ring rot. Pot number 7 was found to have a trace of ring rot. The corresponding control plants in all instances were not affected.

Since only a trace of ring rot developed in the pots and none in the field in which the disease was present in 1939, it appears that under certain conditions, when diseased tubers are present in abnormally large quantity, a few of the bacteria may survive the winter in the soil in North Dakota.

In Florida a total of 906 plants originating from healthy Katahdin seed were planted on the 4th of January 1940 in plots where 25 to 64 per cent of the plants were infected in 1939. These plots were later seeded with 5 barrels of diseased tubers to increase the infestation. No symptoms of the disease were detected in the plants or in the tubers when dug on the 7th of May 1940.

In California two sacks of potatoes known to be healthy were cut carefully to avoid contamination and planted in the field where a high percentage of ring rot had occurred in 1939. A total of 297 hills was dug and examined and no ring rot was found. A small block of healthy potatoes was planted in an experimental plot where more than 50 per cent of the hills showed ring rot in 1939. A total of 848 hills was dug and examined and tubers from 3 hills showed ring rot. It is impossible that these three hills were volunteer plants since a large number of these came up in the plot. An attempt was made to rogue out all volunteer plants, but these might have been overlooked. These results show that there is little likelihood of the ring rot bacteria living over in the soil from one year to the next under California conditions except possibly on volunteer plants.

Preliminary observations indicate that the ring rot organism does not overwinter in the soil under conditions found in Idaho.

Experiments to control ring rot by treating cut seed pieces with various disinfectants.

Extensive experiments were conducted in several states to test the disinfecting value of various chemicals for potato seed pieces

which were infected with bacterial ring rot by the cutting knife, or by contact between diseased and healthy seed pieces.

In California the following disinfectants have been tried on cut seed pieces: iodine, Semesan Bel, Dubay 1230, B-K, potassium permanganate, Cinnex, and Mercurnol. The proprietary materials were used according to instructions on the labels.

These and many other chemicals used in experiments mentioned in other pages of this article are poisonous. Persons unfamiliar with the dangers of handling such poisons should not attempt to use them except under skilled supervision.

Under laboratory conditions 1 per cent iodine solution showed promise as a seed piece disinfectant. But field trials in which cutting-knife-inoculated seed pieces were dipped in 1 per cent iodine solution after cutting, showed severe chemical injury which in most cases resulted in greatly reduced stands. Furthermore, ring rot was not satisfactorily controlled. In one trial the stand was reduced to approximately 12 per cent after iodine treatment and the remaining plants showed 20 per cent diseased hills. Seed pieces dipped in 1 per cent iodine solution and then washed showed 59 per cent stand and 77 per cent diseased hills. A one-half per cent iodine dip showed only slight reduction in stand, but failed to reduce the incidence of ring rot (89 per cent).

Additional tests with iodine as a disinfectant for seed pieces gave erratic results and in general indicate that this method is of little value.

In Oregon seed pieces cut with a ring-rot-contaminated knife were not disinfected by immersing them in an iodine solution for 5 seconds. Dipping infected cut seed in iodine solution for 10 minutes caused a reduction in stand in Idaho, and failed to control the disease.

Various disinfectants were used in California on cut seed. Potassium permanganate solution 1:150 was ineffective in the control of bacterial ring rot. In practically every case where potassium permanganate dip was used, the disease was as severe as in the controls. Semesan Bel dip, 1 lb. to 7½ gallons of water, gave very slight or no reduction in disease. In addition, certain trials showed a serious reduction in stand. In one field trial, with 1:120 solution of Dubay 1230 B S used as a dip, 63 per cent ring rot occurred. Cut seed, dipped in Cinnex solution, had 44 per cent ring rot as compared with 58 per cent for the untreated. Treatment with Mercurnol solution gave 16 per cent ring rot as against 58 per cent for the untreated. However, this treatment showed an 18 per cent reduction in stand.

These treatments show clearly that they give little promise as efficient disinfectants for cut seed.

In Wyoming extensive disinfecting treatments were conducted to determine their effect on ring rot control and on stand and yield.

TABLE 3.—*Treating infected seed before and after cutting and the effect on the incidence of ring rot on stand, and on yield*
Wyoming

Disinfectant	Time of Treatment in Minutes		Stand in Per Cent	Ring Rot Per Cent	Yield in Pounds
	Before Cutting	After Cutting			
Semesan Bel	1		89	15.7	37.7
Do		1	74	1.3	33.5
Cinnex—20	10		84	3.6	38.5
Do		10	81	2.5	38.5
Mercurnol	10		79	0.0	35.5
Do		10	54	1.9	18.0
Corrosive sublimate 1:1000	105		73	0.0	35.7
Do		105	63	1.6	22.7
Corrosive sublimate 1:500	105		70	1.4	26.5
Do		105	62	0.0	22.0
Copper sulfate	15		65	1.5	27.5
Do		15	0	—	
Iodine	1		88	2.4	40.2
Do		1	84	0.0	35.5
Do		15	67	0.0	21.5
Du Bay 1230-BS	½		87	4.6	39.0
Do		½	86	4.6	34.0
Do		15	84	1.2	26.5
B-K (2000 p.p.m)	1		94	3.2	43.2
Do		1	87	3.4	36.5
Do		15	91	5.5	38.0
Check (cut) no treatment			67	6.0	25.0

Because of the small amount of ring rot in the lot of seed used, the differences in percentage of disease were not large, although some were consistently better than others. In the lots treated before cutting there was an average of 3.6 per cent of ring rot whereas in those treated after cutting there was 1.5 per cent. In yield, the

average in lots treated before cutting was 36.00 pounds whereas in those treated after cutting it was 26.7 pounds. Of the treatments used after cutting, mercurnol was the poorest. Practically all of the disinfectants when used after cutting decreased the yields as compared with treatment before cutting. Cinnex 20 was the only disinfectant that did not give such decrease. When used after cutting, longer treating periods than those recommended gave still greater decreases, with the exception of B-K.

TABLE 4.—*Effect of disinfecting seed pieces with* 1 :1000 *corrosive sublimate for* 30 *minutes at different time intervals after cutting with a contaminated knife*

Time Interval between Cutting and Treatment	Stand Per Cent	Ring Rot Per Cent
Immediately	66.7	2.0
15 minutes	86.7	0.0
30 minutes	60.0	2.2
60 minutes	84.0	1.6
2 hours	72.0	0.0
5 hours	69.3	3.8
10 hours	73.3	0.0
24 hours	72.0	3.7
No disinfection	77.3	36.2

In Idaho, improved Semesan Bel, copper sulphate, zinc sulphate, yellow copper oxide, potassium permanganate, iodine, brilliant green, and acidulated corrosive sublimate were used to test cut seed artificially infected. The acidulated corrosive sublimate was the most promising disinfectant, although it did not give complete control. The other chemicals failed to reduce the amount of ring rot appreciably.

In Kansas, seed treatment plots on ring rot control indicated that infection is greatly reduced when the cut seed pieces are treated with acidulated corrosive sublimate solution (1 to 500 + 1% Hcl). It was observed that yield increases in the treated lots were much greater than would be accounted for by differences in the amount of evident ring rot infection. Ring rot was more effectively prevented by treating the cut seed pieces than by treating the whole tubers. Immediate treatment of cut seed was the most effective. In one test where treatment of the cut seed was delayed 12 hours, there were a greater number of evident ring rot infected plants at harvest time and 11 per cent less yield.

In New Jersey the 1-1000 corrosive sublimate 5-minute treatment

of freshly cut seed gave the best control. Preliminary results indicated that merely holding the cut seed in a moist atmosphere to allow molds to appear on the cut surfaces had a beneficial effect on releasing ring rot infention.

In North Dakota, healthy seed pieces were dipped into a bacterial suspension in water and treatments were applied the following day. The seed pieces were planted within 24 hours after treatment. Semesan Bel, yellow oxide of mercury, and potassium permanganate were entirely ineffective in controlling ring rot, whereas the corrosive sublimate and the acidulated corrosive sublimate treatments were highly effective.

Methods of disinfecting cutting knife to prevent spread of ring rot. Since the seed cutting knife is a very important means of spreading ring rot, extensive tests to determine the most efficient and effective manner to disinfect knives have been conducted in several states.

In Florida, knives smeared with *P. sepedonica* from an infected tuber were exposed to different methods of sterilization and then used to cut the tubers into halves. No ring rot infection developed when seed was cut with a contaminated knife that had been boiled for 15 minutes; treated with 1:1000 corrosive sublimate for 5, 10, or 15 minutes; or treated with a 1:15 solution of 40 per cent formaldehyde for 10 or for 15 minutes; or with a 1:30 or a 1:60 solution for 15 minutes. Infection was reduced but not prevented by treatment of the knife with the following solutions of commercial formaldehyde; 1:5 for 5 minutes; 1:30 for 5 or for 10 minutes; 1:60 for 5 or for 10 minutes.

In Montana corrosive sublimate, iodine solution, alcohol, semesan Bel, commercial formaldehyde and acidulated corrosive sublimate were tested as disinfectants.

Corrosive sublimate, acidulated corrosive sublimate, and iodine were entirely satisfactory for disinfecting the cutting knife, but the other materials tested were not effective. In these tests the knife contaminated by cutting through diseased tubers, was disinfected and then used to cut healthy tubers (tested by gram-positive stain method). Both vines and tubers were tested for evidence of ring rot.

In California the cutting knife was found to be the most active agent in the spread of bacterial ring rot. Dipping a contaminated knife for a very short time into a 1 per cent iodine solution before cutting a healthy potato reduced the occurrence of ring rot from 78 to 5 per cent. No injury occurred to the seed piece when the cutting knife was dipped in the iodine solution between each cut. No control in the spread of ring rot by the cutting knife resulted

from the use of 1:150 potassium permanganate solution as a knife disinfectant.

In experiments in Wyoming the cutting knife was drawn through a ring-rot-infected tuber, put into the disinfecting solution to be tested for 10 seconds, and used immediately to cut healthy tubers in half. This procedure was repeated for each tuber cut. The seed pieces were planted the following day. The results are shown in table 5.

TABLE 5.—*The effect of disinfecting the cutting knife on the incidence of ring rot, stand, and on yield in Wyoming*

Treatments	Average Stand	Ring Rot Affected Plants	Yield Average per Row
	Per cent	Per cent	Pounds
Iodine 1%	83.3	0.0	25.0
Copper Sulfate	71.7	6.9	21.6
Formaldehyde (37%) 1:10	68.3	16.7	22.3
Lysol 5%	76.7	0.0	25.3
Corrosive sublimate 1:1000	91.7	4.0	25.3
Corrosive sublimate 1:500	85.0	1.4	27.3
B-K solution 2000 p.p.m.	90.0	1.5	32.3
B-K solution 8000 p.p.m.	88.3	0.0	27.0
Ethyl alcohol 70%	70.0	0.0	21.0
Ethyl alcohol 95%	68.3	1.7	19.0
Bordeaux solution	83.3	4.4	26.3
Lime sulfur (com'l.) 1:20	85.0	49.3	16.6
Mercurnol	80.0	0.0	22.0
Semesan Bel	85.0	13.4	22.0
Cinnex 20	88.3	5.7	28.6
DuBay	80.0	4.9	21.3
No disinfection but inoculation	65.0	30.9	14.3
No inoculation but disinfection	88.3	0.0	22.0

As seen in the table, iodine, lysol, B-K (8000 p.p.m.), ethyl alcohol (70 per cent), and mercurnol gave perfect control of ring rot bacteria on the cutting knife. Only one infected plant was found in each of the following: corrosive sublimate (1:500), B-K (2000 p.p.m.), and ethyl alcohol (95 per cent). Possibly this trace of infection could have been carried by the potatoes, although nothing definite was found in the check lots. Copper sulfate, corrosive sublimate (1:1000), Bordeaux, Cinnex 20, and DuBay lots showed a small percentage of ring rot; formaldehyde and semesan Bel showed higher percentages; and those disinfected with lime sulfur were the most severely diseased.

The stands of the disinfection-lots varied considerably, being highest for corrosive sublimate (91.7 per cent) and lowest (65.0 per cent) for the inoculated check. The yield data did not always coincide with the stand data because of vigor and size differences in the plants. In yield the B-K (2000 p.p.m.) lot averaged highest with 32.3 pounds to the row and the inoculated check the lowest with 14.3 pounds.

In West Virginia the bactericidal effect of phenol, copper sulphate, bichloride of mercury, sodium hypochlorite, and formaldehyde was tested on 15 cultures of *Phytomonas sepedonica*. Of these, sodium hypochlorite and bichloride of mercury were the most effective. The comparative value of these and other chemicals in seed treatment could not be determined because in numerous greenhouse and field experiments, using several methods of inoculation, the amount of successful infection was very small. It is believed that sodium hypochlorite has considerable promise as a disinfectant for (a) containers, (b) machinery. (c) cutting knives, (d) storage houses, and (e) possibly hands of workers.

Spread prevented by the use of whole seed.

In California small whole seed showing 12.5 per cent ring rot potatoes by count were planted, 16 per cent of the hills showed ring rot. The same seed stock cut and planted without seed or knife disinfection had 40 per cent ring rot. In another trial whole seed when planted had 3 per cent diseased hills, whereas seed from the same lot cut in the usual way showed 9 per cent ring rot. These trials clearly indicate the advantage of whole seed in keeping down the spread of ring rot.

The effect of irrigation on the development of ring rot.

In Wyoming untreated seed known to contain ring rot was cut and planted in two two-row plots, each 175 hills long. Irrigation was withheld from one plot while the other plot was irrigated five times to keep the soil moist. Readings for ring rot symptoms were made on the 27th of August, and on the 10th and 19th of September. The following table shows the percentage of plants showing ring rot symptoms at the various readings:

	Aug. 27	Sept. 10	Sept. 19
Dry-land	2.8	9.1	17.1
Irrigated	8.9	27.1	38.8

Ring rot symptoms developed earlier and more rapidly under irrigated than under dry-land conditions. However, the proportion of ring rot on the dry land compared with plants grown on irrigated land increased during the season, showing that it probably takes longer for the disease to develop under dry-land conditions but ultimately it may reach similar proportions.

Difficult to select clean seed from infected seed stock.

Limited trials in California have shown that attempting to select healthy potatoes from ring-rot-infested seed stock is not a safe practice. In 1939, healthy appearing tubers were selected at harvest time from seed lots containing some ring rot. Each tuber was cut at digging time and examined for ring rot and all apparently diseased potatoes were discarded. The rest was held in ordinary cellar storage until the 1940 planting season. These were then cut into seed pieces, the knife being disinfected after each potato. In one test this apparently healthy seed produced 10.5 per cent ring-rot hills and in another trial 4 per cent diseased hills.

Performance of seed from fields which contained only a trace of ring rot.

The question is often asked, is it safe to plant seed from fields which contain only a trace of ring rot? To help solve this problem two-bushel samples of potato tubers from four states were picked at random from fields slightly infected with ring rot and were planted in Alabama in the spring of 1940. One-half of each lot was planted as whole seed, and the other half as cut seed planted immediately after cutting. The amounts of disease showing up in the lots coming from the four states were as follows: whole seed 8, 9, 5 and 2 per cent cut seed: 13, 35, 4, and 2 per cent. This experiment conclusively demonstrated that it is not safe to use seed from fields which contain only a trace of ring rot, even if such seed is to be planted for table stock purposes.

Effect of soft rot bacteria on tubers infected with ring rot.

In Colorado studies were conducted to determine the relation between *Phytomonas sepedonica,* the ring rot organism, and *Erwinia carotovora,* the soft rot organism. No rot was caused by *P. sepedonica* in tubers in the absence of soft rot organisms. When a healthy tuber was inoculated with *E. carotovora* infection failed to develop, but serious and rapid rot developed if the soft rot organism was inoculated in a tuber already infected with ring rot.

The microscopic stem-smear method for indexing ring-rot-infected potato plants.

In Colorado, individual plants were examined for the presence of ring rot in the following manner. When nearly mature but, while the plants were still firm, the lower two to four inches of the stems were cut. These stems were properly marked, placed in a bundle and taken to the laboratory. Smears were made from the stems in the laboratory by using a pair of pliers to squeeze out the juice. Juice extracted from

stems in the laboratory contained less dirt and therefore took the gram stain much better than smears made in the field. Potato plants that by this method proved to be infected were rogued out thoroughly by removing the plant and every tuber. It is believed that the microscopic stem-smear method of indexing potato plants for ring rot will be applicable only in lots grown for foundation seed stock. By using this method ring rot was eliminated from 17 strains of potatoes comprising 10 varieties.

Ring rot detection by means of ultra-violet light.

Using ultra-violet light as a means of detecting ring rot in potato tubers was developed by the Montana Experiment Station. This method has been tested in a number of states with varying results. In Wyoming a fused-quartz ultra-violet generator, 110 volts, a. c., with a special filter, was used. This equipment when used in a darkroom gave freshly cut healthy potato tubers a solid purple color when exposed under its rays. Infected tubers produced a silvery to greenish fluorescence, in contrast to the solid purple color of healthy tubers.

The first tests made with this light in which tubers from a ring-rot lot of seed were examined were not so favorable. After checking the tubers with the light they were planted to see how efficient the check-up had been. In one of the first lots of seed checked, 3.3 per cent ring rot was found, and in another lot about 6 per cent. These were lots of about 100 tubers each. An additional lot of 81 tubers contained no ring rot at all, due presumably to more experience in using the light. The light has been used in potato certification work in examining tubers for ring rot. If any such fluoresence is noted, the tubers are further checked by the stain method. It has been found that ordinarily when the distinctive fluoresence is slight, no ring rot bacteria are found by staining, although this was not always the case. The comment of the Wyoming workers is that this method has a place in the diagnosis of ring rot but it cannot replace the stain method. They believe that it requires considerable time and experimentation to use such a lamp in the most efficient manner.

Ultra-violet light has been used in Minnesota to test many lots of potatoes. It has been possible to differentiate, under proper conditions, between ring rot and healthy tubers by the greenish fluorescence. Also, this method has proven to be useful in differentiating stem end rot from stem end shriveling, net necrosis, slight freezing, and other vascular discolorations due to physiological causes. No ring rot was found on sampling the yield from

a 100-bushel foundation stock that had shown 0.5 per cent with ring-rot fluorescence.

At Beltsville two bushels of potatoes containing considerable ring rot were tested by fluorescent light and gram-stained smears to compare these methods of detecting bacterial ring rot. The lamp used was the Ever Ready Fluoray with No. 67 copper coat Industrial R. electrodes. At first only those tubers that were negative or questionable by the light test were tested by smears; later smears were made from all tubers. In all cases, tubers selected as negative by the light test were also gram-negative and of the questionable cases all except two were gram-negative. Of the 124 tubers with positive fluorescence which were also tested by smears, 41 were gram-positive. It was not possible to differentiate between fluorescence caused by ring rot and that caused by Fusarium or other vascular discolorations. The fact that these tests were conducted at high temperatures may account for the lack of distinct differentiations of different types of fluorescence in tubers affected with vascular discoloration due to various causes.

In Montana where the ultra-violet light method of detecting ring rot in tubers was first used the workers are very enthusiastic about its usefulness in eliminating disease from a seed lot. During the past year they have done extensive work with the light and have learned more about the proper manipulation in operating the light most effectively. They find that by using proper equipment and having complete knowledge of operation the results are highly satisfactory.

In tests using the ultra-violet light method, it was found in every instance that tubers free from fluorescence have been free from ring rot. This statement is based upon many examinations made with the ultra-violet light and in turn checked by the gram-stain method.

As evidence of the accuracy of the ultra-violet light method, 196 tubers were examined by both ultra-violet light and the gram-stain method, with the result that 89 infected tubers were found by both methods. The light indicated 27 additional tubers as suspicious, but all tubers declared free from ring rot using the ultra-violet light method were also declared free using the gram-stain method. Since this experiment, many other tubers have been examined by both methods with similar results. For seed-plot work, disease-free tubers may be positively identified by the ultra-violet light method. The 100 watt, 220 volt, H-4 type black lamp with transformer and Bryant base screw socket have been found to be most satisfactory. Other ultra-violet lamps, including health lamps and certain types of mineral lamps have been tested and found to

be less desirable. *Light examination should be made at temperatures of 40° F. or lower in a totally dark room.* Even short exposures of tubers to higher temperatures during examination reduces the effectiveness of the work. Ring rot will frequently be localized as a single spot in the ring. The light will locate such infection. The gram-stain method, unless the sample is taken around the entire ring, will frequently miss these minimum infections and pass a tuber as sound.

The use of proper disinfectants and proper precautions are as necessary in the use of the light in developing ring-rot-free stock as they are in the examination by the gram-positive stain method.

Varietal resistance to ring rot.

The problem of developing or finding varieties resistant to ring rot is a very important phase of the attempt to successfully control this disease. This is being investigated now by different agencies, and the Wyoming Experiment Station is the first to report on varietal resistance to ring rot.

In this test, 23 commercial varieties and seven promising seedlings were tested for ring-rot resistance. This test consisted of ten-hill rows of each variety, replicated four times. Each seed piece was cut from a different tuber. The cut surface of the seed piece was smeared with the bacterial ooze from a ring rot diseased tuber, and the whole seed piece was then submerged in a water suspension bacterial ooze taken from diseased tubers. The seed pieces were planted with the hand planter on the 11th and 12th of June immediately after being inoculated. The soil was moist as it had been irrigated approximately two weeks before planting, and was kept moist throughout the growing period.

A few plants were showing ring rot symptoms on the 10th of August. Three readings for ring rot symptoms were made, on the 19th of August and on the 10th and 18th of September. In addition, the units showing no ring rot symptoms were again checked on the 27th of September. It was difficult to detect symptoms at this time because some of the plants were maturing and also because some of the leaves had been slightly frosted. For this reason the following table is based on the reading taken on the 18th of September:

All of the varieties and seedlings showed ring rot symptoms in some of the replications except the U. S. D. A. seedling No. 47102. This seedling was entirely free from ring rot symptoms in all the replications on the 18th of September, whereas many of the other varieties had nearly all of the plants infected. U. S. D. A. seedling No. 47102, Rus-

TABLE 6.—*Percentage of plants showing ring rot symptoms in a test of commercial potato varieties and seedlings in Wyoming*

1—Katahdin (U.S.D.A.)	85.0
2—Earlaine (U.S.D.A.)	65.7
3—Chippewa (U.S.D.A.)	96.2
4—Golden (U.S.D.A.)	46.7
5—Katahdin (Wyo.)	90.0
6—Downing	53.0
7—Netted Gem	61.7
8—Burbank	57.5
9—Red McClure	48.5
10—Late Ohio	81.7
11—Brown Beauty	46.0
12—Irish Cobbler	89.0
13—Warba	81.2
14—Chippewa (Wyo.)	85.0
15—Russet Rural	45.2
16—Rural	55.2
17—King	55.5
18—Seedling (Wyo. G., U.S.D.A.—336202)	77.2
19—Pearl	100.0
20—Bliss Triumph	83.2
21—Golden (Wyo.)	69.2
22—Early Ohio	61.2
23—Houma	76.5
24—Sebago	72.0
25—Seedling (Wyo.—512)	54.5
26—Seedling (Wyo.—493)	63.5
27—Seedling (Wyo.—5, U.S.D.A.—46943)	77.2
28—Seedling (Wyo.—25, U.S.D.A.—47055)	94.5
29—Seedling (Wyo.—27, U.S.D.A.—47102)	00.0
30—Seedling (Wyo.—28, U.S.D.A.—47147)	96.5

*Level of significance
*Odds 19:1
***Test consisted of 10-hill rows replicated four times with inoculation of cut seed pieces.

set Rural, Brown Beauty, Golden, Red McClure, Dawning Rural, and King were significantly more resistant than the Pearl, Chippewa, U. S. D. A. seedling 47055, U. S. D. A. seedling 47147, Katahdin, Irish Cobbler, and Bliss Triumph. The Irish Cobbler and Bliss Triumph were among the first varieties to show ring rot symptoms.

Potato seedling resistance to ring rot.

In this test 340 seedlings were tested for ring rot resistance. The test consisted of four-hill units of each seedling, without replication. The seed pieces were inoculated and planted in the same manner as described in the previous test. Readings for symptoms were made on the 23d of August and 18th of September. Table 7 shows the number of seedlings having 0, 1, 2, 3, and 4 plants emerging per four-hill unit, and the number of seedlings having 0, 1, 2, 3, and 4 plants showing

TABLE 7.—*The number of seedlings planted and ring rot results*

Number Plants Emerging Per Unit Planted	Number of Seedlings Planted	Number of Seedlings Showing No Symptoms	Number of Seedlings Showing Ring Rot Symptoms in			
			1 Plant	2 Plants	3 Plants	4 Plants
0	16					
1	33	18	15			
2	58	27	17	14		
3	110	41	23	27	19	
4	123	28	15	32	21	27
Total	340	114	70	73	40	27

ring rot symptoms in each of the above units. The results are based on the reading recorded on the 18th of September.

Ring rot may have been the cause of the plants not coming up in the 0, 1, 2 and 3 plant units. However, from the 340 seedlings planted, 123 or slightly more than 50 per cent produced four-plant units. Of this number, 28 seedlings or 22.7 per cent showed no symptoms of ring rot. Of the 340 seedlings planted, 8 per cent produced four-plant units showing no symptoms of ring rot. The tubers from the ring-rot-free units were saved and will be checked with the ultra-violet ray lamp and by the stain method. Those units testing free from ring rot will be tested in field trials again next year.

Selfed true seed was also saved from the ring-rot-free units.

Educational work on bacterial ring rot of potato.

Dr. R. G. Haskell, senior extension plant pathologist of the U. S. Department of Agriculture, has prepared for the information of growers a report on the activities of different agencies and the seriousness of ring rot.

Various State seed certification services, the Extension Service through the county agricultural agents and various specialists in plant pathology, horticulture, agronomy, and marketing, the agricultural services of railways serving potato sections, fertilizer companies, the press, and others have taken an active part in the ring-rot educational program.

Reports from extension specialists and from the Union Pacific Railroad, as well as from several other sources, indicate that the total effort has been large. Just what are the tangible results in terms of arrested spread or reduced amounts of ring rot is not en-

tirely clear but in some states at least it is evident that progress is being made.

In order to give an idea of the nature of the educational work four states were selected, three of them important in seed production, from the northeastern, northern, central, and northwestern part of the country; and a digest was made of the extension work conducted in each of them in 1940. These states are Maine, Minnesota, Kansas, and Oregon.

Maine—In Maine a very intensive, ring-rot control campaign has been conducted. The State Experiment Station, State Department of Agriculture, Farm Security Administration, fertilizer companies, Bangor and Aroostock Railroad and other organizations have cooperated very closely in this effort. According to Oscar L. Wyman, crops specialist with the Maine Extension Service, the following program has been followed during 1940.

1. Meetings were held in all the important potato communities at which potato ring rot was the chief subject of discussion.

2. At all other potato meetings in all the important potato communities, ring rot was given consideration.

3. Copies of the potato ring rot Bulletin 258, published by the Maine Agricultural Experiment Station in 1939, were distributed.

4. A 1-page leaflet was published giving very concise information about the method of spread and control of the disease. It was distributed through county agents, potato dealers, fertilizer dealers, and various other agencies.

5. Posters paid for by the Bangor and Aroostook Railroad were prepared by the Extension Service and displayed in every store in Aroostook county, including even the women's shops, and in many places of business in the potato-growing area of central Maine.

6. Articles were published in the press and in the Farm Bureau News.

7. Circular letters were mailed to all potato growers.

8. During farm visits county agents were careful to discuss the program with potato growers.

9. Representatives of fertilizer companies and of the Farm Security Administration made bin surveys, and where borrowers had the disease in their potatoes, credit was allowed only when the borrower agreed to follow the approved clean-up practices.

As to progress, Mr. Wyman feels that they still have a big job but are making headway. In 1939, 11 per cent of the potatoes that had passed certification for other diseases were rejected because of ring rot. In 1940 the turndowns because of ring rot were 7½ per cent.

In table-stock fields there has also been a reduction, although less capable of being measured. The county agent working in southern Aroostook county estimated that in 1940 the loss was not more than one-third as great as in the preceding year.

Minnesota—In Minnesota last winter, R. C. Rose, extension plant pathologist, in cooperation with A. R. Miesen of the Northern Pacific Railroad and the county agents, held a series of 23 potato-disease clinics in potato districts. These clinics were widely advertised by means of large colored posters, circular letters, newspaper publicity, and radio announcements. Farmers were asked to bring samples of their seed potatoes for examination to the clinic. A total of 634 samples was brought in and examined by staining and by miscroscopic methods. Ring rot was found in 82 lots and fusarium in 56.

In addition to the clinics, 44 additional meetings were held in various districts in Minnesota, at which ring rot and other potato diseases were discussed. Altogether the specialist met with 67 groups and discussed potato ring rot with 3,300 people.

Another method of informing growers was the planting of eight seed-source trial plots in 6 counties to demonstrate the value of healthy seed stock. Stocks from several hundred farms were included in these plots. Potato tours and plot-visiting days were held in six counties and special schools for potato inspectors were held in two counties.

Kansas—Kansas is a state that depends largely on outside sources for seed. Growers in that state have been informed about ring rot through the educational work headed by John O. Miller, extension plant pathologist.

During the spring several mimeographed news items and circulars were sent widely to newspapers, county agents, and growers. Among these were mimeographed pamphlets on "Irish Potato Seed" and on "Irish Potato Diseases," a new article on "Use of Good Seed Important in 1940" and one on better seed which was sent to all counties where the special potato train made a stop, and an extension circular on potato seed treatment was also sent.

The Union Pacific potato train, operating in cooperation with the Agricultural College and the State Board of Agriculture, made eight stops in the Kaw Valley area of Kansas. A total of 2,870 persons visited the train, inspected exhibits, and heard brief talks on potato diseases. One of the exhibits on the train emphasized ring rot and its control by the use of certified seed.

A number of demonstration plots were established to compare the effects of four different types of seed treatment.

Oregon—An active educational program on ring rot and its control has been followed in Oregon in 1940. E. R. Jackman, extension specialist in farm crops in that state, writes that the following has been done:

1. Winter meetings at which colored slides were shown were held in all the main potato sections.
2. Field meetings were held in all areas where ring rot was present, so that all growers could observe symptoms.
3. Ring rot was featured on the exhibit train of the Union Pacific Railroad.
4. Potato seed treatment tests were outlined in cooperation with county agents and the Department of Plant Pathology.
5. Ring rot was discussed personally with every grower of certified seed in the state.
6. County agents were kept informed by sending them letters and abstracts of papers giving the latest pertinent research results.
7. An additional field inspection was made in connection with certification work.

As an outcome of these efforts and the precautionary methods adopted, Jackman believes that with one exception ring rot has been eliminated from the fields of certified growers.

Cooperation of Railroads—It has already been indicated that several of the railroads cooperated by running potato trains and giving out in other ways information on ring rot control. Those that have come to our attention include the Union Pacific, Northern Pacific, Soo Line, Bangor and Aroostook, and the Atlantic Coast Line.

The Potato Improvement Exhibit Train known as the "Spud Special" of the Union Pacific, is composed of several exhibit cars and three cars for discussions and lectures. This demonstration was organized with a view to obtaining higher yields of better potatoes per acre, and for the improvement of growing, handling, shipping, and marketing methods. Cooperating in furnishing exhibits and personnel for the train were the State agricultural colleges, experiment stations, State and Federal departments of agriculture, and crop improvement and seed growers' associations. The train operated in seven states: Idaho, Oregon, Colorado, Wyoming, Nebraska, Kansas, and Utah; and during its tour from the 22d of January to 22d of February it made 59 stops. Although the weather was sometimes bad, by actual count 35,186 persons visited the train to see the exhibits and hear the illustrated lectures and discussions.

The publicity work that attended the "Spud Special" was very thoroughly done. Every community visited had a potato-train committee, composed of growers and merchants. Newspaper editors began a vigorous news campaign weeks before the train came. Merchants used their advertising space to urge attendance, devoted their store windows to special potato displays, offered prizes of merchandise to visitors at the train.

Radio stations made frequent announcements. Rural telephone companies sent out general calls to all growers on their lines. Handbills and car stickers were distributed. The county agents were the key men in the program. They sent circular letters to potato growers, announced the train at all farm organization meetings, spoke on the radio, and wrote for the press. Vocational agriculture instructors brought their classes and made the potato exhibit train a part of their educational activity.

The potato disease clinics conducted by the states of Minnesota and North Dakota, in cooperation with the Northern Pacific and Soo Line railroads, have already been mentioned in the report for Minnesota. In North Dakota 26 meetings were held with an attendance of 1700 persons. Five hundred samples of seed potatoes were examined and infected lots stained and shown under the microscope, with 45 lots showing positive reaction. All infected lots were table stock from non-certified sources. Approximately 2,000 copies of a special ring-rot circular were distributed at these meetings.

Ring rot from the standpoint of seed potato certification.

The seed certification officials have the responsibility of eliminating disease from the seed stock. With the danger of ring rot in certified seed potatoes, and its subsequent spread to all of the principal potato-producing areas, the inspection officials are faced with one of their most serious problems of recent years.

Mr. Marx Koehnke, chairman of the seed certification committee of the National Potato Association has submitted the following statement:

"The problem of control and elimination of Bacterial Ring Rot, has two general phases, as far as seed certification is concerned, namely, detection and elimination. The matter of detection is complicated, because the usual field symptoms can be masked by a number of other troubles not the least of which is unfavorable climatic conditions. In territories where Ring Rot is just appearing and found to a very slight degree, it is difficult to train both growers and inspectors to detect the disease.

"The difficulty of detection is further complicated by the fact that the means of positive identification is slow and laborious. The adoption of the so-called zero tolerance, being based on positive identification of a trace of the disease, continues to be a source of dissatisfaction among both growers and inspectors.

"The second problem, that of elimination of the disease after detection, is likewise serious. In a territory where the disease has just been found in scattered lots, the foremost difficulty is lack of appreciation on the part of all individuals involved of the seriousness and potential dangers connected with the disease. It seems almost necessary for a grower to have a lot rejected because of the disease, before he becomes appreciative of the critical situation. Other problems then immediately appear to the grower, including how to dispose of infected stock, and disinfecton of the premises and equipment, in order to protect against further infection of other lots, or new stock that may be secured. From the standpoint of the certified grower, the biggest problem is to protect his own seed sources from non-certified lots in the vicinity, particularly in areas of high production.

"It therefore appears that seed certification officials and their staffs have a real job ahead of them, of educating the certified grower and other growers as well, concerning the seriousness of the disease, and eradicating it from communities where it has become rampant. Good producing areas, not having the infection at present, need to show extra vigilance, in order to keep from introducing the disease. These areas, then, will serve as the fountain of new clean seed, to replenish and restock areas where the disease has taken its toll. This job can be done only by thorough cooperation of all individuals in the potato business, including growers, dealers and buying public."

Summary

The results of these various reports show that ring rot of potatoes is highly infectious and readily transmitted by the seed cutting knife; but sometimes it is difficult to infect potato plants by using *Phytomonas sepedonica,* grown on artificial media as the inoculum.

Ring rot is readily transmitted by contact between healthy and infected seed pieces.

Spread by means of an assist-feed planter is negligible, but the picker planter may double or treble the amount of ring rot present in a seed lot.

Sacks in which infected potatoes have been stored may retain the organism for as long as 121 days.

Practically all the evidence indicates that ring-rot spread under natural conditions in the field is not an important factor.

The causal organism does not appear to overwinter in the soil under ordinary conditions, but if an unusually large number of infected tubers are stored in the soil, the organism may still be present in the spring and may occasionally cause infection in potatoes planted in such soil. This fact was demonstrated in an experiment in North Dakota.

Volunteer potato plants may carry the disease from one year to the next.

Corrosive sublimate and acidulated corrosive sublimate gave satisfactory results in controlling the spread of ring rot between healthy and infected seed pieces. Iodine, Semesan Bel, DuBay 1230-BS. potassium permanganate, Cinnex, and Mercurnol were unsatisfactory for the treatment of seed pieces to control ring rot.

Corrosive sublimate, acidulated corrosive sublimate, and 1 per cent iodine solution gave satisfactory results in disinfecting the seed cutting knife, whereas 1:150 potassium permanganate was ineffective.

A large part of the soft rot present in ring-rot tubers results from infection by *Erwinia carotovora.* The ring-rot tubers are highly susceptible to invasion by soft rot organisms.

The gram-stain smear method of testing stems of potato plants for the presence of ring-rot infection has been used to detect the disease in seed stock, and this makes possible the elimination of affected tubers.

The ultra-violet light method for the elimination of diseased tubers has given highly satisfactory results, but proper equipment and complete knowledge of operation is essential for satisfactory results. The light examination should be made at a temperature of 40° F. or lower, and in a totally dark room.

An extensive educational campaign on ring rot was conducted in 1940 by the extension service of State agricultural colleges, the agricultural services of railways serving potato sections, fertilizer companies, the press, and other agencies.

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REPORT OF SEED CERTIFICATION COMMITTEE*

Progress of the Seed Potato Industry—1940

Marx Koehnke

Nebraska Certified Potato Growers, Alliance, Nebr.

The conditions for potato production in the western and northern states were fairly favorable throughout most of the season. Some sections had reported drought conditions during the course of the summer, but in the fall, generally speaking, good conditions of moisture and temperature prevailed, and extremely late frosts were reported from most sections. The result was that the fields that were started as a normal or average-sized crop resulted in large to bumper yields in many areas.

Reports received generally from the western and northern states revealed that the storage houses were taxed to capacity with the certified crop that was produced. The crop, as a whole, was of good quality, but mechanical injury, because of the immaturity of the crop, caused a great deal of damage at harvest time. The actual yields from various territories will probably be printed in the American Potato Journal in the near future. These records are being assembled by the Crop Reporting Board of the Agricultural Marketing Service, Washington, D. C. This report will not include the production of certified seed in the United States, for that reason.

The Fifth Annual Conference of the High Plains Potato Workers was held from the 16th to 18th of August, at Monte Vista, Colorado. This is located in the famed San Luis Valley, between the mountain ranges in southern Colorado. This meeting was well attended by seed certification officials, extension service workers and other people interested in potato production. Representatives from the U. S. D. A. and the following states were present: Utah, New Mexico, Arizona, Texas, Louisiana, Nebraska, Wyoming, Montana, Idaho and Colorado. Practically all phases of the potato production were discussed and field meetings were on the program. A lively discussion of Psyllid Yellow control and Ring Rot problems were features of the conference.

As a result of the conference held in Colorado and discussions with various state officials during the course of the season, it is evi-

*Paper presented at the 27th annual meeting of the Potato Association of America, Philadelphia, Pennsylvania, December 30, 1940.

dent that the Ring Rot disease has become more wide-spread and is causing much more concern among inspection officials, as well as growers, through the western states, during the last year. Some state officials and other individuals closely connected with the seed production industry are frankly discouraged over the situation. They feel that the disease in a number of states has become more severe, and is taking a larger toll of certified fields, as well as commercial production, in a number of sections. The extreme difficulty of detection of the disease, under conditions other than very favorable for field inspection, renders its location and control more difficult. The inability to develop a serious attitude on the part of many potato growers stands in the way of effective control of the disease for the time being.

The fact that it has infected foundation seed stocks in several territories has an ominous aspect. The lack of adequate information in many phases of the problems connected with this disease renders it more difficult to handle from the standpoint of seed certification, particularly.

In the western and northern states, from the Great Lakes to the Rocky Mountains, insect infestations were much smaller this season than has been the case for several years. Psyllid Yellows was almost entirely absent from many of the sections where any serious trouble has occurred in the past. Only a few areas reported grasshopper difficulties during 1940. A few sections had early outbreaks of Blister Beetle infestations, but these were soon brought under control. Territories which are customarily affected with flea beetle are similarly affected this season. In Nebraska, particularly, control experiments have been initiated by the Agricultural College, and it is hoped that some benefit will be gained from this source.

Recommendations of the Committee

1. It is strongly recommended that more research work be initiated on bacterial ring rot by State Experiment Stations as well as the U. S. D. A. The present effort toward coordinated research being directed by U. S. D. A. Potato Project in cooperation with the Potato Research Committee of the Potato Association of America should be continued and strengthened.

2. Strict application of the so-called zero tolerances with respect to ring rot by seed certification agencies and further research on this disease to determine if slight tolerances are desirable.

3. Continuation of the experimental work by the U. S. D. A.

relative to the effect of virus diseases on yields (Recommended in 1939).

4. Encourage education in both producing and receiving states to further the sale and distribution of certified seed potatoes. This may involve considerable education through state extension services, state departments of agriculture and directly to growers by seed-certification agencies themselves.

5. Seed certification agencies should give special consideration to the production and distribution of foundation seed stocks. (Also recommended in 1939).

6. Seed certification agencies should be given consideration when quarantines are set up by other states against certain localities. This applies particularly to diseases, such as Hair Sprout, that occur without warning, and cannot be readily detected. Special methods of controlling such diseases will need to be set up by the states in which they occur. Caution is urged on the setting up of quarantine restrictions against other states until a fair hearing, or consideration, is given in the state against which the quarantine is to be placed.

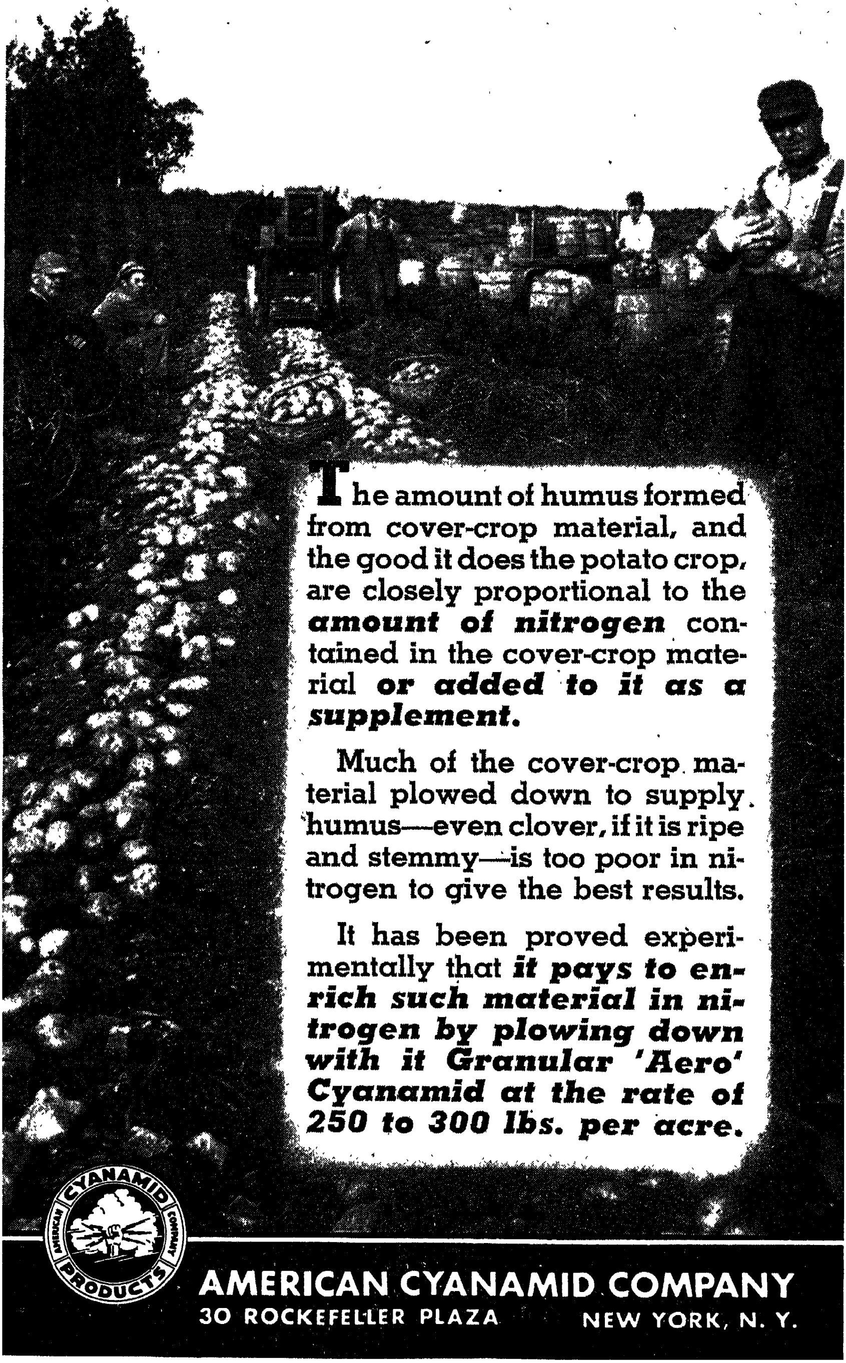
7. In all states, the seed certification program should be developed hand in hand with all other potato programs within the state, such as plant pathology, horticulture, agronomy, plant breeding, etc. Also recommended in 1939).

8. All state certification agencies should work in close cooperation with the U. S. Department of Agriculture, and the states, in introducing new varieties. It is suggested that a technical description of each new variety be published when it is released for commercial production.

9. Continue to announce various meetings, sectional conferences of general interest to potato workers well in advance of the time of meeting, in the American Potato Journal.

10. Carry more articles in Journal for popular consumption. Also suggest earlier publication of articles of seasonable interest, so that value shall not be lost to readers.

11. "In view of possible demands for more certified seed potatoes in Central and South American countries from Continental United States, it is suggested that a special committee of the Potato Association of America be appointed to make definite studies and recommendations on possible demands and supplies of certified seed potatoes for these new areas. It is also suggested that the United States Department of Agriculture undertake very definite experiments in this connection."


The amount of humus formed from cover-crop material, and the good it does the potato crop, are closely proportional to the ***amount of nitrogen*** contained in the cover-crop material ***or added to it as a supplement.***
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E. B. Tussing, State University, Columbus, Ohio (Service Inactive)

G. M. Bentley, Dept. of Agriculture, Knoxville, Tennessee (Increasing)

S. F. Grubbs, Virginia Crop Improvement Assn., Blacksburg, Va. (Inactive)

F. Waldo Craig, Dept. of Agriculture, Charlestown, W. Virginia (Service Inactive)

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THE REAPPEARANCE OF POTATO SCAB IN INFESTED AND ITS APPEARANCE IN ALMOST UNINFESTED LAND

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The previous condition and history of the plot with its present physical and biological properties are as follows:

The central plot was utilized during 1914, 1915 and 1916 as a testing ground for a number of varieties of potatoes (Lutman, 4). The land was known to be infested with scab organisms at that time and had apparently been a portion of an old garden with an easily worked, quick, sandy loam. It had once been heavily fertilized with farm manure. At the conclusion of the variety tests, the plot reverted to field cultivation with a variety of crops such as corn, oats and clover, but no potatoes. Much of the fertilizer used during these nineteen years was manure of pigs fed with city garbage and uneaten portions of this garbage. During the last eight years of this period, ending in 1936, records of bacterial counts (plating-out method) and the soil moisture were taken monthly.

In 1935 the plot was replanted with disinfected Green Mountain seed,—commercial fertilizer being used. The important fact deduced from the crop was that the scab organisms had lost their pathogenicity or had all died off during the nineteen-year interval. Instead of nearly one hundred per cent scabby tubers in susceptible varieties, the percentage of badly scabbed tubers had declined to 3.3 per cent, and 70 per cent of the total were clean. On the other hand, many of the 70 per cent which was considered to be clean presented a brown russeted appearance just as dug. The brown layer dried down and was so

inconspicuous on the dried tubers that they would have passed for one of the russeted varieties. Some tubers, however, showed the deep, typical pock marks of ordinary scab.

These results induced further investigations on the types of scab which had appeared and on the possible further increase in the percentage of typical deep scab. This plot was therefore planted, 1935 to 1940 inclusive, six years, with disinfected (although already clean) Green Mountain tubers and fertilized with commercial fertilizer. The potatoes were usually harvested about the middle of September.

In 1935 variations in the amount and severity of scabbing in various parts of the plot had been noted. The scab was at its maximum in the same regions as nineteen years before, also the russeting. No record was made while the rows were dug, but the differences could not be disregarded.

In the 1937 harvest the records were taken only for the rows to the south, middle and north. Some differences were to be observed here since the north rows had more clean tubers than those of the middle and south. The relatively clean area extended here from the west end of the plot further to the east. The segregation—south, middle and north—was not entirely successful, so the following year the data were taken in a different manner.

In the 1937 harvest the data were divided into two parts, *i. e.,* from the west part of the plot and from the east and south parts. As the table shows, the west part of the plot had a much higher percentage of clean tubers than had the middle and south. At this time the necessity of a scab map of the plot became evident and a rather general one was made, as shown in figure 1. The tubers from the rows were brought to the end of each row and examined. A similar one was made from the data of the preceding year. The map was continued the following year in still greater detail. Figure 2 on the maps for the three years indicates the site of the bacteriological tests of the preceding years. The number 2 was retained for the following years, but as new soil samples for soil tests or bacteriological counts were found necessary, additional numbers and regions were chosen:

No. 1 Lightest, sandiest soil and least amount of scab.

No. 2. Original sampling region with a high percentage of scab.

No. 3. Heaviest soil, wettest, and with highest percentage of scab.

Nos. 4 and 5. In new plots; No. 4 is fairly heavy land with little scab and No. 5 is lighter, sandy loam, also with a minimum of scab.

In 1938 the original plot was increased three-fold by adding wings of the same size to the north and south. This soil was glacial

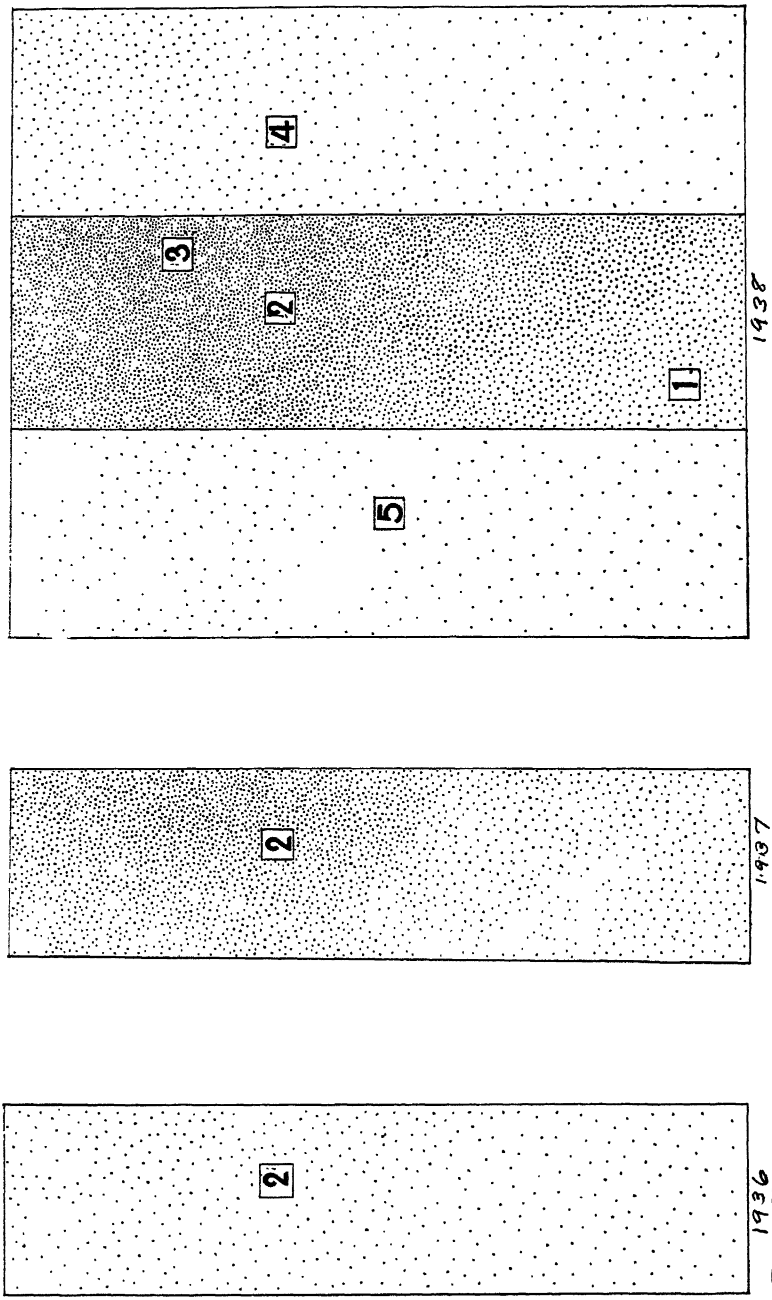

FIGURE No. 1.—Potato scab map of the plots. The percentage of scab is indicated by the dots, but these have no numerical significance. The map for 1939 and 1940 would have been very similar to that for 1938.

drift, very similar in structure and texture to the central third (see plan), and each section with about sixteen rows. Planted in 1937 in silage corn, no potatoes had been grown there for more than thirty years to the knowledge of the writer. The previous summer had been dry with a bad drought in mid-August which cut the crop short from tip burn, but the 1938 summer was hot and humid with an abundance of showers during the growing season. The foliage was rank and tender, so in spite of several sprayings with Bordeaux mixture, some late blight appeared in the north part of the plot and the harvesting was started in early September. All the observations on the incidence of scab were completed before rot had developed.

Taken as a whole, the old plot produced only 13.2 per cent of clean tubers, whereas the new ones yielded 91.1 per cent. On the other hand,

TABLE 1.—*First series of trials*

Year	Variety	Clean Tubers Per cent	Slightly Scabby Tubers Per cent	Badly Scabby Tubers Per cent
1914	Vermont	11.6	70.8	18.2
	Gold Coin and Norcross	3.1	43.2	43.7
1915	Green Mountain	4.4	42.8	52.8
1916	Green Mountain	...	0.8	99.2

Second series of trials
All Green Mountains

Year	Plot Location	Per cents		
		Clean	Slighty Scabbed	Badly Scabbed
1935	Entire Old Plot	70.2	26.5	3.3
1936	South	48.2	44.5	7.3
	Middle	18.5	63.1	18.4
	North	57.5	39.4	3.1
	Total	45.2	47.0	8.8
1937	West	25.6	31.3	43.1
	Middle and south	6.3	73.7	20.0
	Total	17.6	49.0	33.6
1938	Old plot	13.2	51.6	35.3
	New plots	91.1	8.6	0.3
1939	Old plot	5.3	35.0	59.7
	New plots	54.6	41.8	3.6
1940	Old plot	0.0	15.0	85.0
	New plots	40.0	45.0	15.0

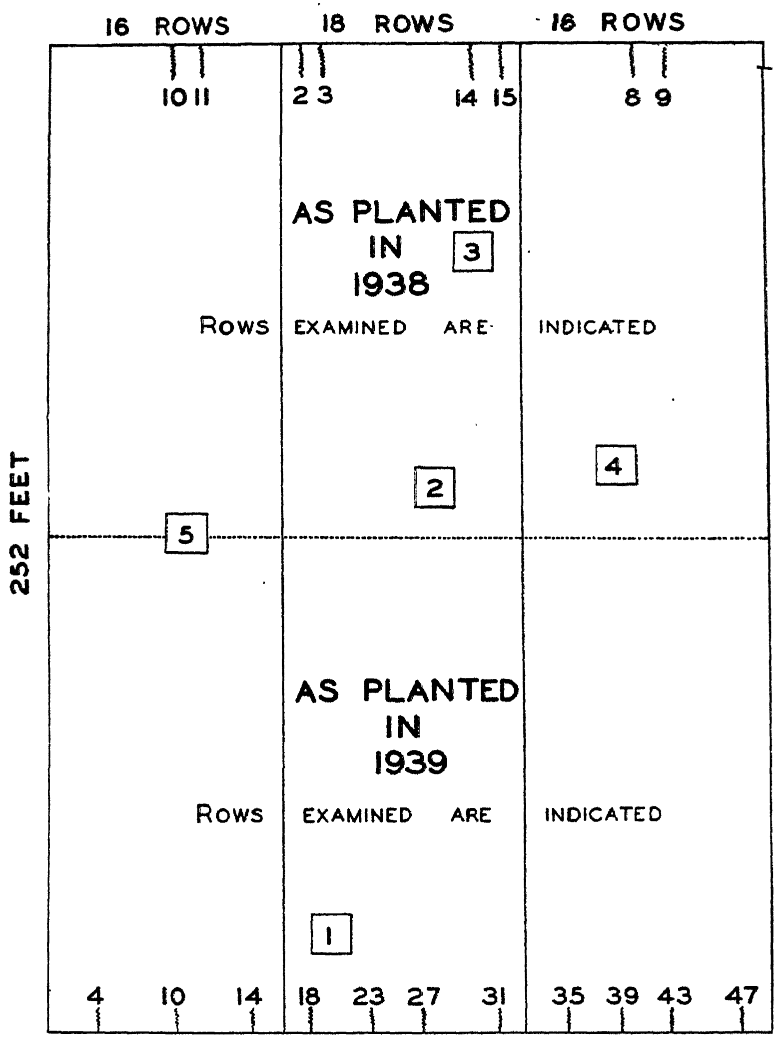

FIGURE No. 2.—Map of the plot to show the planting in 1938 and 1939 as well as the location of the regions from which soil was taken for bacterial and moisture data; figures are in the squares.

the old land yielded 35.3 per cent of badly scabbed ones against only 0.3 of 1 per cent on the new land.

The rows (Fig. 1) in each plot (16 rows) were numbered one to sixteen, so the four rows selected were from the northern and southern portions of the old plot. Rows 10 and 11 were at the middle of the north new plot, as were the 8 and 9 on the south new plot.

Scabbiness is shown by dotted shading in figure 1. The dots do not mean number of scabby tubers. The percentages of clean, slightly scabby and badly scabby tubers can be seen in table 2 on which this part of the text figure is based.

The large number of slightly and badly scabbed tubers on the old plot is to be contrasted with the small numbers on the new plots. No marked differences in scab were seen in the two new plots to the north and south of the old one.

The results were so interesting on these new and old plots that the experiments were repeated in 1939 and 1940. At the harvest, care was used to examine more rows and to tabulate the results according to the position of the plants in the row, as shown in figure 2. The general results for the old and new plots are shown in table squares table 1. Clean tuber percentages had diminished on both old and new plots, at the same time slightly and badly scabby ones increased. The percentage of scab on the old plot had now become almost as high as in 1916 when it had risen nearly to 100 per cent badly scabbed. In the 1939 harvest many

TABLE 2.—*Results in* 1938

Plot used in 1936-1937-1938

		Tubers			Per cents		
		Clean	Slightly Scabby	Badly Scabby	Clean	Slightly Scabby	Badly Scabby
Rows 2 and 3	West end	146	181	57	38	47	15
	Middle	49	195	128	13	52	35
	East end	34	121	85	14	50	36
Rows 14 and 15	West end	1	134	315	0	30	70
	Middle	18	234	107	5	65	30
	East end	23	190	32	10	78	12

New plot (north), used only in 1938

		Clean	Slightly Scabby	Badly Scabby	Clean	Slightly Scabby	Badly Scabby
Rows 10 and 11	West end	298	25	3	91	8	1
	Middle	356	31	1	92	8	0
	East end	498	34	2	93	7	0

New plot (south), used only in 1938

		Clean	Slightly Scabby	Badly Scabby	Clean	Slightly Scabby	Badly Scabby
Rows 8 and 9	West end	213	25	0	90	10	0
	Middle	295	24	0	90	8	0
	East end	167	36	0	82	18	0

tubers were still only slightly scabbed but scab-producing actinomyces must have been present in every cubic inch of the plot.

A detailed analysis of the rows and plots is presented in table 2.

The entire plot contained 48 rows, of which the first 16 rows were on the north new land; rows 17 to 32 were on the older land; and rows 33 to 48 were on the south new land. Some rows, such as numbers 4 and 10 on the north third and numbers 43 and 47 on the south section, were as far away as possible from the badly infected central section. Some rows, numbers 14 and 35, were taken on the new land for comparison with numbers 18 and 31 on the old plot.

Badly scabbed tubers were almost entirely lacking in rows distant from the old plot, for example, numbers 4 and 10 on the north and numbers 39, 43 and 47 on the south plots. A comparison of one of these rows with number 14 or number 35 shows the contaminating effect of the old plot. Row 14 showed 9.3 per cent badly scabbed tubers, whereas row 18, twelve feet away had 38.6 per cent; still more striking was row 35 with only 3 per cent badly scabbed, with row 31 located in the worst infested section of the old plot had 67.5 per cent.

These comparisons are very striking in view of the fact that ordinary farm practices were followed in the preparation of the land without any attempt at sanitation other than plowing, harrowing, and furrowing from east to west.

The weather seemed to have little effect on the gradual rise of scab in the old plot. The years 1935 and 1936 were average years on rainfall and temperature; 1937 was very hot and dry during August; 1938 was hot, muggy, with numerous showers during August; 1939 and 1940 were average in temperature and rainfall. The weather conditions did not do anything to check the steady increase of badly scabbed tubers.

Causes for the Return of Scab

The factors usually assigned as stimulators of potato scab, in addition, of course, to the presence of the organisms, are the following: (1) a moderate alkaline reaction to the soil, (2) abundant humus, (3) good aeration with not too much moisture.

None of these factors would seem, at first glance, to induce the return of the pathogenic types of actinomyces. The pH had always been approximately 6.8. The amount of humus has not been increased and, during the years that this experiment was conducted, it must have actually diminished since increasing the commercial fertilizer added none. The soil was well aerated—a very light sandy loam even in the

TABLE 3—*Bacterial counts and soil moisture in 1928*

Date	Plot No.	Moisture	Total Organisms	*Actinomyces chromogenus*	*Act. albus*	Remarks
March 31	1	12.9	16,500,000	2,000,000	150,000	Frost had been out of the ground for only about 10 days
	2	22.9	36,100,000	2,500,000	100,000	
	3	19.7	36,500,000	600,000	150,000	
July 7	1	14.5	5,250,000	650,000	50,000	Heavy rain for several days just before samples were taken
	2	14.8	5,600,000	850,000	50,000	
	3	18.3	9,450,000	1,050,000	105,000	
	4*	15.5	22,400,000	900,000	90,000	
	5*	19.0	12,850,000	400,000	40,000	

*In corn the preceding year.

Soil moisture in 1939

Plot Number	June 16 Per cent	July 1 Per cent	July 14 Per cent	July 28 Per cent	August 8 Per cent	August 10 Per cent	August 18 Per cent	August 22 Per cent	August 24 Per cent
1	11.8	14.2	9.2	4.1	11.2	6.4	6.4	3.1	6.0
2	18.3	19.8	12.8	4.8	11.6	10.8	9.4	6.6	4.5
3	19.7	21.2	12.8	5.2	12.6	12.9	10.4	9.9	6.4
4	15.5	19.0	19.5	5.8	11.2	8.9	8.9	2.2	5.2
5	18.3	18.3	17.3	6.2	8.7	12.9	9.2	6.2	6.4
6	West end of north new land					9.5			
7	East end of north new land					10.1			
8	Between No. 1 and No. 2 old land					8.9			
9	East end of south new land					11.5			
10	West end of south new land					14.0			

Plate counts were made a number of times during the summer, but they indicated nothing new. The Actinomyces were abundant at all parts of the growing season and in all soils. The percentage of Actinomyces approximated usually about 25 per cent to 35 per cent of the total number of organisms.

heaviest parts—and in no part could the soil be said to be really wet except immediately after a heavy rain, and even then the soil could be cultivated in a few hours, because the drainage was so rapid.

No adequate explanation, therefore, can be suggested for the return of scab on the old plot. The markedly pathogenic strains were present during the long interval of nineteen years between the two plantings of potatoes or the 26.5 per cent slightly scabbed and the 3.3 per cent badly scabbed tubers would not have shown in 1935. Were the russeted tubers which were quite abundant this year a transitional stage in the development of disease producing tendencies—tendencies not limited to an infection of the lenticels but of any region of the entire skin? Sanford's theory (9) that soil actinomycetes live on humus but transfer their activities to potatoes when they have the opportunity would seem to be a very plausible one. Deep scabs undoubtedly develop around young stomata or lenticels, but the majority of actinomycetes require some years to learn to infect early and grow rapidly with the growing tuber. Earliness of infection undoubtedly has much to do with the depth and size of scabs. The varying number of cork cambial layers (one to three) observed by Smith (1931) probably represents *weather periods* favorable for the extension of the parasite into the host tissue. The nature of the favorable periods might vary with the type of soil: on heavy, poorly drained clay the parasite might only advance during the dry periods when aeration was good; on light, sandy loam the organism would make its progress during, or after rains, when the soil held enough moisture to further its growth.

The Spread of Scab to Uninfested Land

The author has shown (3) that scab may occur on tubers grown on plots in openings in old pine forests. The addition of two plots, one north and one south of the old one in this experiment, was not such a clear-cut example, but is of value since the additions had both physically and chemically the same type of soil.

Any cultivation would necessarily carry over some infested soil from the old plot to this new land. Even in the first year (1938) when the middle rows of the new plots were examined (Nos. 10 and 11 on the north and 8 and 9 on the south) a few potatoes were badly scabbed (0.3 of 1 per cent) and more were slightly scabbed (8.6 per cent). The notable rise the following year in both slightly and badly scabbed could hardly be attributed to cultivation, although it might. It would seem that the markedly pathogenic actinomyces were establishing themselves in this soil and acquiring a parasitic habit.

TABLE 4.—*Percentages of the clean, slightly and badly scabbed potatoes*

1939

	Row 4 Per cent	Row 10 Per cent	Row 14 Per cent	Row 18 Per cent	Row 23 Per cent	Row 27 Per cent	Row 31 Per cent	Row 35 Per cent	Row 39 Per cent	Row 43 Per cent	Row 47 Per cent
West											
Clean	66	76	47	25	9	8	9	48	66	64	73
Slight	33	24	50	66	68	48	9	49	33	35	26
Bad	1	1	3	9	26	44	82	3	1	1	1
Middle											
Clean	58	34	34	11	0	0	1	28	49	58	57
Slight	40	29	61	64	30	10	11	67	50	40	40
Bad	1	0	5	24	70	90	88	5	1	2	3
East											
Clean	65	69	19	1	0	0	4	47	63	52	39
Slight	34	30	59	48	0	0	28	51	66	46	58
Bad	1	2	22	52	100	100	68	2	1	2	3
Plot Averages											
Clean	[illegible]	5[illegible]			5				54		
Slight	[illegible]	4[illegible]			35				44		
Bad	[illegible]	4			60				2		

TABLE 5.—*The amount and retention of soil moisture*—1940

Plot Number	July 12 A few hours after heavy rain; soil moist, but not sticky.	July 16 Just after a heavy rain; soil, sticky.	July 18 Samples taken 36 hours after previous lot; soil, quite dry.	July 29 54 hours after a rain; soil, very dry.	August 2 72 hours after a rain; soil, dry.
	Percentage Moisture	Percentage Moisture	Percentage Moisture	Percentage Moisture	Percentage Moisture
1	10.0	17.3	9.1	6.0	5.8
2	15.8	25.4	13.8	8.2	7.7
3	17.3	42.0	16.5	15.3	15.0
4	14.5	24.3	13.5	10.9	9.4
5	15.3	23.1	9.2	9.0	8.9

TABLE 6—*Percentages of clean, slightly, and badly scabbed potatoes*
1940

	Row 5 Per cent	Row 9 Per cent	Row 12 Per cent	Row 16 Per cent	Row 20 Per cent	Row 24 Per cent	Row 28 Per cent	Row 32 Per cent	Row 37 Per cent	Row 41 Per cent	Row 45 Per cent	Row 48 Per cent
West												
Clean	52	49	34	23	5	0	0	7	34	30	52	60
Slight	35	40	45	25	29	25	18	65	59	64	45	39
Bad	13	11	21	52	66	75	72	28	6	6	3	1
Middle												
Clean	56	31	42	40	0	0	0	1	50	39	52	49
Slight	29	43	45	29	15	19	5	50	49	60	42	46
Bad	15	26	13	31	89	81	94	49	1	1	6	5
East												
Clean	53	13	16	3	0	3	0	0	20	20	23	21
Slight	40	44	39	29	21	22	5	10	68	55	60	55
Bad	7	43	45	68	79	75	95	90	12	25	17	24

Plot Averages	Rows 5, 9, 12	Rows 24, 28	Rows 41, 45, 48
Clean	39	0	42
Slight	39	15	50
Bad	22	85	8

Bacterial and Moisture Differences

Unfortunately, no method has been discovered by which pathogenic actinomyces strains can be differentiated from the saprophytic ones on bacterial plates. The scab types are, in general, brown color-producing on nutrient agar.

Actinomycetes, determined by plate counts during the monthly trials for eight years, varied from month to month, but approximated about 20 per cent of the total numbers of organisms. To determine the effects of the return to potato culture, moisture and bacterial contents were taken a number of times from various parts of the field during the years 1938, 1939 and 1940, as shown in table 3.

Like most glacial drift soils of this region, variations are so numerous that an acre of uniform characteristics (so necessary for experimental work) is almost an impossibility. The proportions of gravel, coarse sand, fine sand, clay and humus vary, depending on the material the glacier dumped on this particular spot. This composition affects the physical properties of the soil, especially the absorption and retention of water.

The humus content was determined by incineration and approximated, in all the various locations at which samples had been taken, three per cent.The pH, determined in 1934 by the colorimetric method for the soil in the middle section, showed pH 6.8. Tests repeated in 1938, with soil from the various plots numbers 1-5, gave a pH ranging from 6.4 to 6.7.

Size of the soil particles. On the middle plot section, number 1 showed the least amount of scab, whereas section number 2 showed severe infection. The soil at number 1 was very light and sandy; that at number 2, a sandy loam, as even a very casual inspection showed. Samples were later taken also from numbers 3, 4, and 5. In order to compare these five soils, rather large composite samples weighing two to three pounds were brought into the laboratory and passed through a fine sieve to remove the small stones. The soils were then packed into five ungraduated 500 cc. cylinders to the same height, 6.3 cm. The cylinders were then filled with water and the contents churned back and forth until all clumps were broken when they were placed upright and the soils allowed to settle sediment out.

After standing twenty-four hours, the jars, figure 3, were examined with a horizontal microscope equipped with a micrometer scale in the eyepiece. The magnification was quite low since many of the sand grains to be examined were very large. The sizes of the small

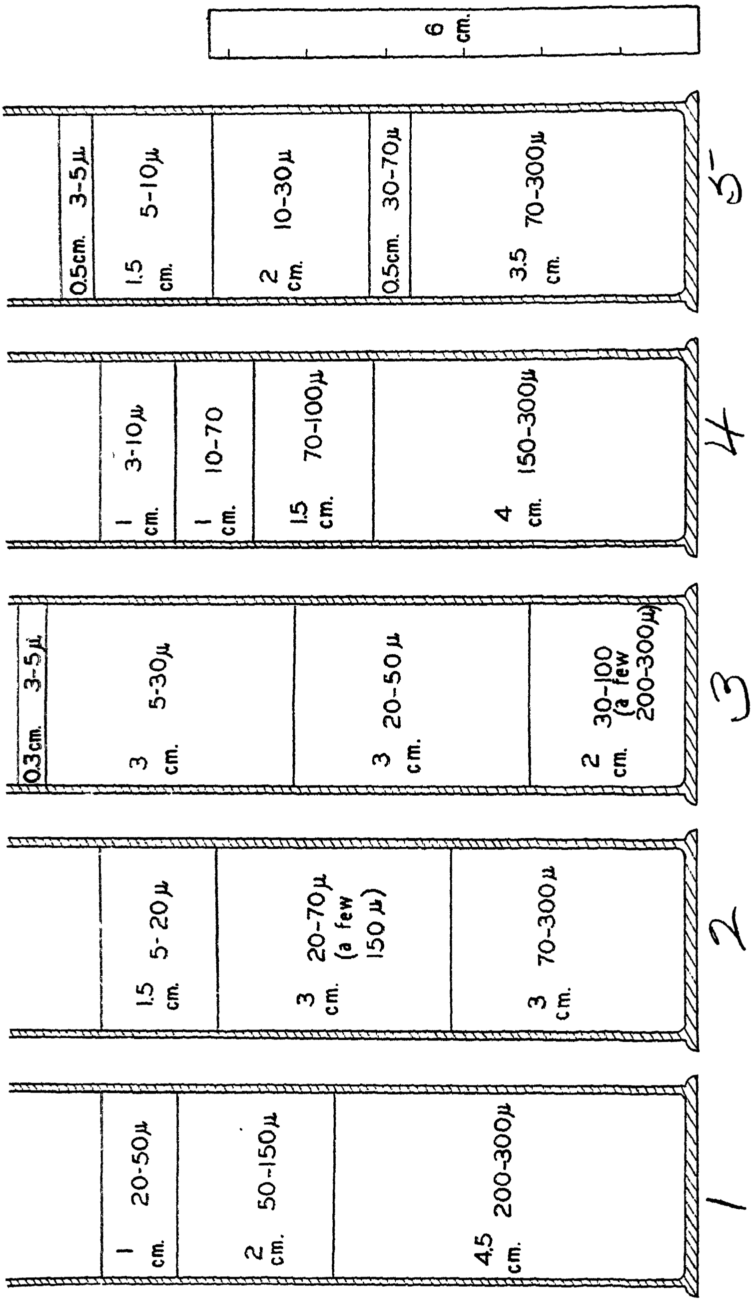

FIGURE No. 3.—Sizes of the soil particles from five locations on the plots, as indicated by sedimentation.

particles in the upper layers of some of the cylinders had to be estimated. The separation was not perfect in a single sedimentation since occasional pieces were mixed with those much smaller. The method, however, does give a fairly accurate picture of the abundance of the various soil components. Soil number 1 was composed of quite large sand grains with few small ones and no very fine ones. Soil number 2 had some of the coarse material, but had also quite a layer of the fine particles. Soil number 3 had no very large grains, was composed of very fine particles and of a layer of particles not much larger than bacteria. In soil number 4, the coarser particles again predominated, but about a quarter of it consisted of smaller ones. Soil number 5 was similar to soil number 3 but with more of the larger sand particles.

Correlating the size of sand particles with water content, water-holding power, and percentage of scabbing, numbers 4 and 5 do not need to be considered since they represent the newer plots. A high percentage of scab is associated with high water content, the ability to hold water, and a predominance of small soil particles. The soil where the tubers scabbed badly always seemed damp after a rain, while that in No. 1 where the scabbing was at a minimum was quite dry only a few hours after the rain had ceased. The acidity of the plots was the same in the different plots so that this factor could be eliminated. The difference lay in the amount of water held.

The number of bacteria and their activity are in direct proportion to the size of the soil particles. Organisms find moisture (and food) in the film of water which surrounds each soil particle during the greater part of the year; at times during heavy rains and for much of the winter the interparticle spaces are also filled with water. This water-logged condition is not conducive to the growth of the very numerous and important aerobes, although it may spread them into other soil films and break up clumps attached to soil particles. The critical periods for bacteria are those of drought or low water content.

The size of the soil particles determines the area of their total surface film, Rahn (8); large sand particles have only a very small area as compared with that of the same particles broken into fifty pieces. Each break makes a new surface and a new layer of film for bacterial growth.

Soil particle differences, so very marked on the small plot used in this experiment, may have exerted a role also in the scab infection. The parasitic actinomyces which were usually held closely appressed to the soil particles were released by heavy rains and came into contact with the small tubers. The lenticels opened and grew in the moist soil and easy infection resulted.

Soil moisture content may be too high; so high that many inter-

particle spaces are flooded. The aerobes then have an abundance of water, but lack the equally essential oxygen and do not thrive. The roots require almost the same conditions; the water optimum for both root and bacterial growth is the same and, providing the acidity is the same, is the determining factor.

This conclusion would seem to contradict that of Sanford (9, 10) that a high moisture content prevented infection, but it really confirms it, since the lowest percentage of moisture he tested, 14 per cent was much more than the wettest of any part of this plot except during the winter or after a rain. The critical period for infection is during the last two weeks of July when the tubers are forming and do not exceed the size of a pea. Lenticel and skin infection at this time are likely to lead to the large, deep scabs.

The plots used for this experiment were not ideal for potato land; the soil was too light and sandy to hold moisture during the rather dry weather of August. The yield was especially light in the region of number 1. The moisture relations supplement that of Sanford, furnishing a moisture range below that which he investigated and one below that at which the potato plant does its best. The author would agree with Goss (2) and Sanford (10) that scab is at its worst in soil that is best for the potato plant, *i. e.*, one which can hold a medium moisture content at the time when the plant is making its most rapid growth.

General Conclusions

Other factors (acidity, humus, previous infection) being approximately similar, soil moisture and the ability to retain moisture are the dominant elements in relatively light sandy loam soil.

Soil once infested by scab organisms can be freed from their activity and five to six years of continuous cultivation in potatoes are necessary to cause severe and almost complete scabbing.

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THE INFLUENCE OF SPLIT APPLICATIONS OF COMPLETE FERTILIZER ON THE YIELD OF IRISH POTATOES*

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For some time it has been known that nitrogen, phosphorus, and potassium applied to certain crops early in the season may be partly leached away or fixed in the soil before the plants mature. When this happens, it is possible that the plants are deprived of sufficient nutrients during the latter part of the growing season when they are in greatest need.

Carolus (1) has shown that potatoes have a large total requirement of nitrogen, phosphorus, potassium, magnesium, and calcium, the maximum nutrient requirement being from 50 to 80 days after planting. Hester, (2) working with tomatoes, also found that a large portion of the nutrient was absorbed by the plant between the second and third months after transplanting.

The conventional time of applying potato fertilizer in West Virginia is at planting, but it is conceivable that fertilizer, applied later in the season, in a position where it can be utilized efficiently by the plants, may increase the yield.

A small minority of West Virginia farmers apply their potato fertilizer in split applications without knowing the effect on the crop. This fact, together with the possibility that fertilizer applied early in the season may be partly leached away or fixed in the soil before the plants mature, led the author to undertake the present investigation.

EXPERIMENTAL PROCEDURE

The experimental work was begun in 1939 and was continued through the 1940 season. Four separate field trials were conducted, two of these with the Irish Cobbler variety, and one with Rural Russet, all three of which were conducted on a DeKalb silt loam soil at the Arthurdale Experimental Farm at an altitude of 1800 feet. The fourth was conducted with the Irish Cobbler on a Wheeling sandy loam soil at the Lakin Experimental Farm at 600 feet. The same plot arrangement and also identical treatments were used in all cases.

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All treatments had supplied 1500 pounds per acre of a 5-10-10 fertilizer mixture by the time the potatoes were in full bloom. The amount and time of applications are indicated below.

Treatment	At Planting	At Breaking	At Blossoming
Check	1500	0	0
1	1000	500	0
2	1000	0	500
3	500	1000	0
4	500	0	1000
5	500	500	500

At planting time the fertilizer was distributed uniformly in the row and thoroughly mixed with the soil by means of a garden plow before the crop was planted. At breaking time or when most of the plants appeared above ground, the fertilizer was applied in bands six inches to each side of the row and four inches deep. The last application was made when the potatoes were coming into bloom. This was also applied four inches deep but eighteen inches from the row. To determine the location of the different fertilizer applications a careful examination of the extent of root growth was made. In order to prevent mechanical injury the fertilizer was then applied slightly beyond the lateral root tips. The last two applications were followed by cultivation.

One trial at Lakin and one at Arthurdale contained six replications whereas the other two trials contained five. Each replication consisted of three-row plots fifty feet long and three feet between the rows. Exactly sixty seed pieces, cut uniformly, were planted in each row. In all of the trials, check plots appeared systematically throughout the planting. This made possible more efficient use of Student's methods of statistical analysis.

The potatoes were harvested two weeks after the vines were dead, and the weights of potatoes of the U. S. Number 1 grade and the total yields from the center row of each plot, were then recorded. An analysis of each trial is shown in table 1.

Presentation of Data

In all trials, with the exception of treatment 4, which consistently yielded significantly less than any other treatment, the dfferences were not generally uniform in either degree or direction but there was apparently a definite trend to indicate the additional value of the fertilizer applications made during the early part of the season.

TABLE 1—*A comparison of the mean plot yields of Irish Cobblers.*
ARTHURDALE EXPERIMENT FARM, 1939

	U. S. No. 1's			Total Yield		
Treatment	Mean Yield in Lbs. Per 50 Ft. Row	Difference from Check	Odds	Mean Yield in Lbs. Per 50 Ft. Row	Difference from Check	Odds
Check	31.5			36.5		
No. 1	27.5	—4.0	32:1	32.5	—4.0	23:1
Check	30.3			35.3		
No. 2	28.7	—1.6	5:1	33.8	—1.5	7:1
Check	32.3			37.5		
No. 3	26.8	—5.6	10:1	32.3	—5.2	11:1
Check	31.6			36.6		
No. 4	18.6	—13.0	495:1	24.2	—12.4	108:1
Check	31.6			37.6		
No. 5	27.2	—4.4	12:1	31.9	—5.7	48:1

A comparison of the mean plot yields of Irish Cobblers
ARTHURDALE EXPERIMENT FARM, 1940

Check	44.3			53.4		
No. 1	48.3	+4.0	56:1	55.8	+2.4	12:1
Check	44.0			53.3		
No. 2	40.1	—3.9	68:1	49.8	—3.5	176:1
Check	44.0			54.1		
No. 3	47.4	+3.4	13:1	55.3	+1.2	4:1
Check	42.0			52.0		
No. 4	31.8	—10.2	558:1	42.6	—9.4	361:1
Check	39.5			49.3		
No. 5	40.0	+0.5	none	50.2	+0.9	none

A comparison of the mean plot yields of Irish Cobblers
LAKIN EXPERIMENT FARM, 1940

Check	66.6			71.7		
No. 1	67.0	+0.4	none	72.2	+0.5	none
Check	65.1			71.8		
No. 2	63.7	—1.6	2:1	68.8	—3.0	5:1
Check	65.1			71.7		
No. 3	63.8	—1.3	2:1	69.1	—2.6	3:1
Check	66.7			72.1		
No. 4	59.7	—7.0	1428:1	65.7	—6.4	3332:1
Check	67.6			72.3		
No. 5	65.1	—2.5	6:1	71.4	—0.9	2:1

A comparison of the mean plot yields of Rural Russets
ARTHURDALE EXPERIMENT FARM, 1940

Check	42.4			50.0		
No. 1	42.5	+0.1	none	49.0	—1.0	2:1
Check	43.4			50.8		
No. 2	40.9	—2.9	76:1	48.3	—2.5	28:1
Check	41.8			49.3		
No. 3	45.0	+3.2	5:1	50.9	+1.6	2:1
Check	40.9			48.5		
No. 4	30.1	—10.8	515:1	38.9	—9.6	224:1
Check	41.4			49.0		
No. 5	40.6	—0.8	3:1	47.9	—1.1	3:1

TABLE 2—*A summarization of the mean plot yields from the four field trials*

	U. S. No. 1's			Total Yield		
Treatment	Yield (Lbs.)	Difference	Odds	Yield (Lbs.)	Difference	Odds
Check No. 1	46.2 46.4	+0.2	none	52.9 52.4	—0.5	none
Check No. 2	45.7 43.3	—2.4	80:1	52.8 50.2	—2.6	221:1
Check No. 3	45.8 45.8	0.0	none	53.1 51.9	—1.8	6:1
Check No. 4	45.3 35.1	—10.2	271:1	52.3 42.9	—9.4	434:1
Check No. 5	45.0 43.2	—1.8	10:1	52.1 50.4	—1.7	5:1
No. 1 No. 2	46.4 43.4	—3.0	8:1	52.4 50.2	—2.2	7:1
No. 1 No. 3	46.4 45.8	—0.6	2:1	52.4 51.9	—0.5	2:1
No. 1 No. 4	46.4 35.1	—11.3	171:1	52.4 42.9	—9.5	280:1
No. 1 No. 5	46.4 43.2	—3.2	10:1	52.4 50.4	—2.0	10:1
No. 2 No. 3	43.3 45.8	+2.5	6:1	50.2 51.9	+1.7	3:1
No. 2 No. 4	43.3 35.1	—8.2	163:1	50.2 42.9	—7.3	118:1
No. 2 No. 5	43.3 43.2	—0.1	none	50.2 50.4	+0.2	none
No. 3 No. 4	45.8 35.1	—10.7	65:1	51.9 42.9	—9.0	82:1
No. 3 No. 5	45.8 43.2	—2.6	6:1	51.9 50.4	—1.5	3:1
No. 4 No. 5	35.1 43.2	+8.1	434.1	42.9 50.4	—7.5	540:1

In order to summarize these trials more concisely, a comparison of the mean plot yields of the four field trials were combined in table 2. The Rural Russet variety was included in this comparison because it behaved like the Irish Cobbler.

This summarization clearly shows that in no case, except treatment 1, was the yield from the split applications greater than the check or single application at planting. The yield difference between the check

and treatment 1 was so small, that for all practical purposes it can be discarded. The checks were significantly more productive than treatments 2 and 4 which received a substantial amount of fertilizer at blossoming time. The yield differences between the checks and treatment 3, which received 1500 pounds, and treatment 5, which received 1000 pounds by breaking time, were not significant but still there was a tendency for the checks to excel.

Conclusions

It is evident from the data listed in tables 1 and 2 that the longer the fertilizer application was delayed after planting, within the limits used in this experiment, the lower the yield. This indicates that the response from the fertilizer applied after planting was not so great as from that applied at planting time. These data also tend to support the belief that there was very little foraging effect, under the experimental conditions, between the two rows of potatoes spaced three feet apart on the Wheeling sandy loam or the DeKalb silt loam soil, since the potato plants apparently made little use of the fertilizer placed eighteen inches away from the row.

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POTATO CULTURE AND STORAGE INVESTIGATIONS IN 1940[1]

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Comparatively few investigations that might be classed as cultural and storage were reported in current literature during the year. A very large proportion of the potato reports of an agronomic nature have dealt with fertilization. These are summarized in a separate paper to be published in the American Potato Journal. This is a brief review of reports involving cultural practices, seed, varieties, and storage. As

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usual none of the articles published in the Journal in 1940 is discussed here, these being merely referred to in the bibliography.

Culture

Magrou, Legroux and Bouget (12) found that seeds of potatoes, disinfected by hydrogen peroxide and sown in sterile test tubes on cotton, soaked in Knop solution containing a suitable proportion of glucose and glycerine, give aseptic plantlets capable of tuberization. Primary tubers coming from aseptic sowing of the seeds on the slopes of Pri de Midi at an elevation of 1400 to 1700 meters produced marketaable tubers. The maladies of the virus are not transmitted by the seeds and the tubers issued from the aseptic seedlings were unquestionably exempt. Further work is to be done in finding a means of fighting against potato diseases.

Field studies, with the Triumph variety of potatoes for fall planting were conducted by Cordner (6) for two years, 1938-1939. Cut and whole tubers for fall planting were tested as well as chemical treatment with ethylene chlorhydrin and variation in age of seed. Each treatment was represented by four to six plots and, when possible, Latin squares were used. The results of the 1938 trials indicated the stand of plants from cut sets to be generally superior to that obtained from whole tubers and the best emergence to be obtained from cut seed planted 32 days after harvest and treated with ethylene chlorhydrin. The emergence of untreated seed improved with the age of the seed. Additional data were secured in 1939, when the most significant factor was "date of planting" because of the hot weather. However, highly significant differences were obtained due to kind of seed. Chemical treatment is necessary to get prompt sprouting when the seed tubers are in a state of rest, although after a period ranging from 35 to 40 days with Triumph potatoes, cutting alone is sufficient to induce rapid germination. Although data are not conclusive with pre-sprouting, it appears to be more advantageous in the earlier unirrigated plantings, this being especially true with whole tubers. By the use of a straw mulch which was helpful in conserving soil moisture and lowering the soil temperature a higher rate of emergence, stand of plants and yield of tubers were obtained.

Edmundson (9) published a bulletin on potato production in the western states. He gives general information on potato production referring particularly to Arizona, California, Colorado, Idaho, Montana, northwestern Nebraska, Nevada, New Mexico, Oregon, Utah, Wash-

ington and Wyoming where potato production is largely confined to irrigated sections. Questions on crop rotation, selection and improvement of soil, importance of good seed, disinfection, cutting, and care of freshly cut seed are discussed. Planting depth and spacing, irrigation, and cultivation methods, spraying, dusting, harvesting and marketing and storage are also considered. Dry-land potato production is briefly discussed. A few of the important factors regarding potato production in each state are presented.

Barbut, Chevalier and Gausserand (2) report general cultural experiments conducted for two years, 1938-'39 in Algeria. These consisted of fertilizer studies, variety trials, spacing experiments, study of size of seed pieces, and a study of ecological factors. Chemical analyses of tubers were also made from the plots which were fertilized with different materials. The choice of variety was found to increase harvest yields by 94 per cent. A 40 per cent difference in yield was found between potatoes growing in the summer and winter months, this difference being attributed to heat. Nutritional studies are not complete but show the need for a number of quickly available nutrients. A 25 per cent variation in yield was observed by varying the density of the plants in the field and from 16 per cent to 30 per cent variation occurred in different sizes of seed pieces.

Seed

Cordner and Ward (7) of Oklahoma presented results of experiments on the handling and preparation of seed. Dormant and nondormant tubers of the Triumph variety were used for the tests which were conducted in 1938 under controlled greenhouse conditions to determine the relation of seed preparation and temperature to the germination of potato tubers and sets. Later in that year sprouted tubers were compared with unsprouted tubers and a study of the factor of tuber size was made. Decay of tubers and sets is indicated to be caused by a physiological disturbance similar to blackheart. Newly cut sets germinated more rapidly and better than did whole tubers, this fact, especially true at high temperatures. Chemical treatment with ethylene chlorhydrin for 24 hours favored germination only when whole tubers were planted. Storing tubers at high temperatures seemingly reduced the seed value, especially when whole tubers were used for planting. Prompt sprouting, especially in the case of whole tubers, appears to result in less breakdown and a higher per cent of germination. The recommendation is made for the use of newly-cut sets for the fall crops planting in comparison with the recommendation of planting whole tubers in the spring.

Storage

The cause and control of the brown or black discoloration commonly referred to as sunscald on skinned or "feathered" potatoes were recently investigated by Rose and Fisher (17). Skinned tubers were exposed to rapidly moving air currents of both high and low humidity and similarly to still air. No blackening of the skinned areas occurred on those tubers exposed to warm air of high humidity. Six distinct varieties were used. When similar tubers were exposed to air of 80 to 85 per cent relative humidity at 40° to 50° temperature, blackening occurred within an hour. The authors concluded that conditions immediately following harvest which are favorable to rapid desiccation are most likely to cause blackening. The trouble is least likely to occur where conditions favor rapid wound healing such as warm humid days.

Varieties

Bukasov (3) collected thousands of specimens of potatoes, both wild and cultivated species from 1925 to 1932, in South America and Mexico and carried them to Russia for study and use as breeding material. It was found necessary to study the species under short day condition for proper evaluation with *S. tuberosum*. Breeding work was conducted with species found immune to *Phytophthora infestans*, wart, powdery scab (*Spongospora subterranea*), blackleg (*Bacillus phytophthorus*) and bacterial wilt (*Bacillus solanacearum*). Breeding work was also done to obtain frost-resistant species, early-maturing species and species with a high protein content.

MacMillan (11) gives a general review of literature dealing with the history and the evidence on the origin of the potato. From this it was found that the point of origin remains still unnamed. The prevailing opinion of its origin is that the cultivated potato originated from more than one wild species, and probably from several. It is felt, however, that a wild potato descended directly from the parents of our present *S. tuberosum* by seed or vegetative means may yet be found growing in some undiscovered spot.

Pal (15) of India reported that 300 samples of potatoes obtained from different parts of India were studied by the Imperial Agricultural Research Institute, at Pusa and later at Delhi. Many stocks were eliminated as being synonymous; representative samples of the remainder were sent to Ormskirk, England for identification. The number of varieties cultivated in India are few; most of the commercially important varieties represent old, possibly unidentifiable varieties. A description of the three most generally grown varieties is given.

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POTATO QUALITY IV

RELATION OF VARIETY AND ENVIRONMENTAL CONDITION TO PARTIAL COMPOSITION AND COOKING QUALITY*

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From the results of a recent survey Hotchkiss *et al* (5) state that mealiness and whiteness are the cooking qualities most desired by both household and institute buyers. The results of other surveys have also indicated that these two are the most important quality factors. Therefore, in this study only texture (mealiness) and color (whiteness) are considered.

Several investigators (2), (4), (7), have reported on the influence of environment on the cooking quality of certain varieties of potatoes. However, the author knows of no study of this kind wherein the effect on chemical composition was also studied. The purpose of this investigation was threefold: (1) to determine the cooking quality of several standard varieties by physical measurement (specific gravity tests) and cooking tests; (2) to determine the effect of widely varying types of environment on the cooking quality of the several varieties; and (3) to determine by chemical analyses the differences in composition between varieties and the differences caused by the different types of environment. It was thought that if certain types or

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characteristics of composition could be associated with certain varieties and quality ratings, that some fundamental information concerning the factors affecting quality would be forthcoming.

Material and Methods

The potatoes used for cooking tests and chemical analyses in these experiments were grown in four different regions of New York State. Each of these regions presented a distinctly different environmental condition. In table 1 are presented the names of counties in which the samples were grown, the soil type, and the fertilizer applied.

TABLE 1—*Location where grown, soil type, and fertilizer application*

County	Soil Type	Fertilizer Application
Tompkins	Canfield Silt Loam	1500 #/A. 5-10-5
Steuben	Bath Gravelly Silt Loam	1000 #/A. 4-8-12
Suffolk	Sassafras Silt Loam	2000 #/A. 5-10-5
Wayne	Muck	1000 #/A. 5-10-15

With the exception of Suffolk County, ten varieties were grown at each location. These varieties were: Green Mountain, Pioneer Rural, Houma, Sebago, Katahdin, Warba, Cobbler, Pontiac, Chippewa and Earlaine. Pontiac and Pioneer Rural varieties were not grown in the Suffolk County plots. Seed from this same source was used at each location.

At harvest time approximately 60 to 70 tubers of each variety at each of three of the locations were taken. Twenty to 30 tuber samples were taken from the Wayne County Plots.

The specific gravity of the tubers was determined according to the method described by Clark *et al* (2), using a series of sodium chloride solutions in which the difference in specific gravity between successive solutions was .004. The average specific gravity was calculated and a sample of tubers to be used for cooking tests and chemical analyses was selected within a narrow range near the average specific gravity. Selected in this way, a small sample was more nearly representative of the lot than when taken from the lot at random.

Dry weight, starch, total nitrogen, protein nitrogen, and tyrosine were estimated and in all cases expressed as per cent of fresh weight.

Six tubers were used for the cooking sample. Partially standardized boiling tests were used. The same size and kind of porcelain containers were used for all samples. A similar amount of water was used, definite time for boiling, and uniform gas flames were used. Observations and ratings were confined to texture and color. A rating of 10 was given the samples which showed optimum mealiness and a rating of 1 to those which showed extreme sogginess. Likewise, a rating of 10 was given to samples which showed no blackening one-half hour after boiling, and a rating of 1 to samples which showed extreme blackening. Samples exhibiting intermediate texture and blackening were given appropriate ratings.

TABLE 2.—*Average specific gravity*

Variety	County Where Grown				Average
	Tompkins	Steuben	Suffolk	Wayne	
Green Mountain	1.099 (1)*	1.098 (1)	1.087 (1)	1.077 (1)	1.090 (1)
Pioneer Rural	1.095 (3)	1.094 (2)	....	1.074 (2,3)	1.088 (2)
Houma	1.088 (5)	1.090 (3)	1.082 (2)	1.074 (2,3)	1.084 (3)
Sebago	1.098 (2)	1.086 (5)	1.072 (6)	1.064 (6)	1.080 (4,5)
Katahdin	1.092. (4)	1.090 (4)	1.075 (3,4)	1.063 (7)	1.080 (4,5)
Warba	1.087 (6)	1.080 (6)	1.073 (5)	1.066 (5)	1.077 (6,7)
Cobbler	1.085 (7)	1.078 (8)	1.075 (3,4)	1.070 (4)	1.077 (6,7)
Pontiac	1.081 (8)	1.077 (9)	....	1.062 (8,9)	1.073 (8)
Chippewa	1.073 (10)	1.079 (7)	1.067 (7)	1.062 (9)	1.070 (9,10)
Earlaine	1.079 (9)	1.076 (10)	1.062 (8)	1.061 (10)	1.070 (9,10)

*The figure in parenthesis indicates the rank.

RESULTS

Specific Gravity Measurements:—The results of the specific gravity determinations are presented in table 2. The data presented in this table show a marked difference in specific gravity among the various varieties. These differences are fairly consistent and are present even when the varieties were grown under widely varying soil and other environmental conditions. At all four locations Green Mountain tubers were highest in specific gravity; also the Pioneer Rural tubers

TABLE 3.—*Per cent of dry weight and starch, and starch protein ratio*

Variety	Dry Weight				Starch				Starch/Protein Ratio			
	Tompkins	Steuben	Suffolk	Wayne	Tompkins	Steuben	Suffolk	Wayne	Tompkins	Steuben	Suffolk	Wayne
Green Mt.	25.80	25.22	22.53	21.44	19.26	19.26	16.45	15.97	10.5/1	9.8/1	14.8/1	16.0/1
Pioneer Rural	23.33	24.04	....	20.72	17.08	18.41	....	15.22	12.1/1	12.4/1	....	17.8/1
Houma	22.48	23.67	21.78	19.69	16.79	18.36	16.17	15.54	10.3/1	11.8/1	14.0/1	19.7/1
Sebago	25.47	21.38	20.42	18.21	19.21	15.65	15.66	12.55	11.7/1	8.7/1	11.6/1	9.7/1
Katahdin	24.12	23.57	20.40	17.81	18.42	18.01	15.24	12.11	11.0/1	10.5/1	10.8/1	9.7/1
Warba	22.99	21.01	20.15	18.53	17.30	16.85	14.79	13.01	11.3/1	10.4/1	13.0/1	14.6/1
Cobbler	22.00	21.07	20.60	20.52	16.13	16.05	14.96	14.39	8.7/1	10.2/1	12.2/1	15.2/1
Pontiac	21.53	21.83	....	17.07	15.20	15.99	....	12.50	10.0/1	11.3/1	....	14.0/1
Chippewa	19.01	20.44	17.63	16.28	13.44	14.74	13.13	11.88	10.8/1	10.6/1	12.1/1	13.3/1
Earlaine	21.27	20.88	17.78	16.98	14.83	15.60	13.81	11.41	11.7/1	9.4/1	13.6/1	11.4/1

were ranked consistently high. Pontiac, Chippewa, and Earlaine varieties were low and, with one exception, were the lowest three. Houma, Sebago, Katahdin, Warba, and Cobbler were usually intermediate and their rank varied somewhat among the four locations.

Bewell (1), Haddock and Blood (4) and others have reported a high correlation between specific gravity and texture. Since fairly large and consistent differences were found in specific gravity between varieties, and within varieties between regions, it was expected that corresponding differences in mealiness would be noted in cooking tests. This was found to be true and is discussed more fully in connection with the results of cooking tests.

Partial Chemical Composition:—The percentages of dry weight and starch, and the starch protein ratio are presented in table 3.

Dry Weight and Starch:—Green Mountain and Pioneer Rural varieties are consistently high in per cent dry weight and starch. Likewise, as was the case in specific gravity measurements, Pontiac, Earlaine, and Chippewa are usually lowest. Houma, Sebago, Katahdin, Warba and Cobbler are intermediate and usually there is not a great difference between any two of them.

Starch/Protein Ratio:—Many investigators have attempted to correlate starch/protein ratios with mealiness. The results presented in this paper indicate that the starch/protein ratio is not necessarily related to mealiness. The highest ratios were found in tubers from Suffolk and Wayne Counties and, as may be noted in table 5, the tubers grown at these locations were consistently much less mealy than those from Steuben and Tompkins counties. There also appears to be no relationship between starch/protein ratio and variety.

The percentages of total nitrogen, protein nitrogen, and tyrosine are presented in table 4.

Total Nitrogen:—The environmental conditions under which the tubers are grown had more influence on the nitrogen content than did variety. No consistent differences may be noted between varieties, however, in nine of the ten varieties the highest per cent of nitrogen was found in tubers from Steuben County. Tubers from Tompkins County were next in rank and those from Suffolk and Wayne counties were the lowest. Since all varieties were more mealy when grown in Steuben and Tompkins counties, it appears that a high degree of mealiness and a high nitrogen content are not incompatible.

TABLE 4.—*Nitrogen fractions in tubers*

Variety	Total Nitrogen				Protein/Nitrogen				Tyrosine			
	Tompkins	Steuben	Suffolk	Wayne	Tompkins	Steuben	Suffolk	Wayne	Tompkins	Steuben	Suffolk	Wayne
Green Mt.	.396	.423	.283	.255	.294	.314	.177	.160	.021	.021	.032	.029
Pioneer Rural	.347	.352	....	.232	.226	.228	....	.137	.017	.022	....	.035
Houma	.395	.360	.272	.197	.261	.248	.185	.126	.022	.020	.028	.023
Sebago	.369	.389	.286	.335	.263	.289	.216	.206	.013	.016	.034	.027
Katahdin	.391	.401	.337	.338	.267	.274	.225	.199	.021	.015	.026	.027
Warba	.382	.384	.332	.282	.245	.260	.182	.153	.019	.018	.029	.028
Cobbler	.358	.379	.323	.226	.298	.253	.197	.151	.032	.025	.039	.029
Pontiac	.313	.360	....	.230	.185	.227	....	.143	.019	.026	....	.027
Chippewa	.316	.380	.275	.282	.199	.222	.174	.143	.013	0.31	.015	.033
Earlaine	.347	.380	.308	.316	.203	.267	.163	.160	.040	0.31	.050	.046

Protein Nitrogen:—There appears to be no discernible relationship between the per cent of protein nitrogen and variety. However, as with the per cent of total nitrogen, most of the varieties grown in Steuben County were highest in per cent of protein nitrogen, with those from Tompkins, Suffolk, and Wayne counties following in that order.

Tyrosine:—In the above it has been pointed out that the percentages of total nitrogen and protein nitrogen are consistently higher in all varieties from Steuben and Tompkins counties than in those from Suffolk and Wayne counties. The reverse appears to be true in the case of the tyrosine fraction. Although no relation between variety and tyrosine content can be detected it may be easily noted that the per cent of tyrosine in Suffolk and Wayne counties' crop is consistently higher. Tottingham *et al* (8) and others have reported that the amount of tyrosine present is an important factor in the blackening of boiled potatoes. The black pigment which is formed supposedly is melanin which is formed by oxidation of tyrosine or related phenols. From the data presented here, however, it appears that the amount of blackening is not related directly to the amount of tyrosine present.

Cooking Tests: The results of the cooking tests are presented in table 5.

Texture: The texture ratings show definitely that there are marked differences in cooking quality among the various varieties. They also indicate that the varieties tend to maintain their relative order in regard to texture, even under widely varying environmental conditions. All of the varieties grown in Tompkins and Steuben counties were much more mealy than those from Wayne and Suffolk counties. Green Mountain and Pioneer Rural were consistently rated high, and Chippewa and Pontiac, and Earlaine definitely inferior. Houma, Sebago, Katahdin, and Cobbler could be termed intermediate in texture.

The important implications that are to be drawn from these results are that both variety and environmental conditions are about equally important and that under various types of environmental conditions the varieties tend to rank in the same order. However, under one set of environmental conditions the Chippewa, Earlaine or Pontiac may be more mealy and of better quality than the Green Mountain or Pioneer Rural grown under less favorable conditions.

Color:—No blackening was observed in tubers from Wayne County and very little in those from Suffolk County. However, practically all varieties from Steuben and Tompkins counties showed some blackening. Green Mountain, Pioneer Rural, and Sebago tubers blackened most seriously, whereas Houma, Pontiac, and Chippewa blackened the least.

TABLE 5.—*Observations on cooking quality*

Variety	Texture*					Color**				
	Tompkins	Steuben	Suffolk	Wayne	Avg.	Tompkins	Steuben	Suffolk	Wayne	Avg.
Green Mt.	10	10	6	6	8	6	6	9	10	7.8
Pioneer Rural	10	10	—	4	8	9	4	—	10	7.7
Houma	4	6	3	2	5	10	8	10	10	9.5
Sebago	10	10	3	2	6.25	9	5	10	10	8.8
Katahdin	8	9	2	3	5.5	9	7	9	10	8.8
Warba	9	6.5	3	3	5.4	9	8	10	10	9.3
Cobbler	9	6	4	3	5.5	9	7	10	10	9.0
Pontiac	8	6	—	2	5.3	10	9	—	10	9.7
Chippewa	2	6.5	2	1	5.1	9	9	10	10	9.5
Earlaine	5	3	1	2	2.8	7	10	10	10	9.3
Average	7.5	7.3	3.0	2.8		8.7	7.3	9.8	10.0	

* 10 = most mealy
1 = extremely soggy
** 10 = white one-half hour after boiling
1 = extremely black

Discussion

Green Mountain and Pioneer Rural varieties were found to be more mealy than the other varieties. Pontiac, Chippewa, and Earlaine were usually the least mealy. Cobb (3) states that temperature is the most important environmental factor influencing mealiness. This being the case, Green Mountain and Pioneer Rural would profit more from the lower average temperature during the period of tuber formation than those varieties which mature much earlier. All varieties grown in Tompkins and Steuben counties matured much later and under conditions of lower temperatures, thus possibly partially explaining why tubers from those regions are more mealy than those from Suffolk and Wayne counties.

There appeared to be an inverse relationship between mealiness and blackening. Those varieties which were most mealy also showed the greatest amount of blackening. Nash and Smith (6) have suggested that lack of sufficient sunlight and low temperatures are important in influencing the occurrence of blackening. The results do indicate that the varieties which mature under higher temperatures and more favorable light conditions do show a lesser degree of blackening. In Wayne and Suffolk counties where all varieties matured early and under conditions of higher light and temperature, little or no blackening was found. The results of chemical analysis do not help to explain why certain varieties blacken and others do not, or why certain varieties blacken more when grown in certain regions.

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RESPONSE OF SEVERAL VARIETIES OF POTATOES TO DIFFERENT PHOTOPERIODS

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Studies were conducted in the greenhouse at Greeley, Colorado, during the winter of 1937-'38 and 1938-'39 to determine the effect of 9-, 11-, 13-, and 17-hour photoperiods on vine growth, and the development of flower, fruit and seed of the potato. For the sake of brevity the winter of 1937-'38 will be referred to as 1938, and the winter of 1938-'39 as 1939. Each series was exposed to daylight from 7 A. M. until 4 P. M., then covered with black cloth. The 17-hour plants were supplied with artificial light from the time of covering until midnight, the 13-hour plants until 8 P. M., and the 11-hour plants until 6 P. M. The 9-hour plants received no artificial light.

Artificial light was supplied as soon as the plants emerged from the soil. The lights consisted of 60-Watt lamps with 10-inch reflectors spaced 3 feet apart. They were placed 3 feet above the greenhouse bench and raised as the plants grew in height. The intensity of this artificial light ranged, at bench level, from approximately 20-30 foot candles. The lights were turned off at the specified time by alarm clocks which pulled a pin and allowed a weight to drop, releasing a knife switch. This mechanical device operated very satisfactorily.

The first year 10 varieties were used. All plots were not replicated but in each plot there were 6 plants of each variety and these were randomized. The second year the plots consisted of 10 varieties of 3 plants each planted in duplicate, and the plots and varieties randomized. Each plot was planted with whole tubers. These were set 9 x 9 inches and 3 inches deep.

Planting operations were conducted on the 1st of December both years. During the first year all the plants had emerged by the 12th of January, the second year by the 10th of January. However, in both years most of the plants had emerged 26 to 30 days after planting. When approximately 2 inches high, they were pruned to one stem.

The greenhouse extends east and west with a head house at the west end. No plantings were made closer than 12 feet from the head house.

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The north center bench used for the tests was 45 feet long and 6 feet wide. Although some place-effect was noted, the general growing conditions were similar,—there being very little difference in the intensity of the sunlight or in the air temperature. High humidity was maintained during the day by sprinkling the walks and the soil under the benches.

A night temperature of 55° F. and a day temperature of 70° to 75° were maintained, although the day temperature occasionally was higher for short periods in the afternoon.

Soil temperatures throughout the bench were fairly uniform, varying generally from one to three degrees, although variations of 4° to 5° F. occasionally occurred. The greatest variation in the soil temperature was during the mid-afternoon. Nine soil thermometers were used to record the soil temperature. These were spaced at intervals, three in the center of the bench and three on each side, 9 inches from the outer edge. The temperature was taken at a depth of 3 inches, the soil being approximately 6 inches deep in the bench.

During January, February and March in 1938, 58 days were fair or mostly fair, 26 partly cloudy and 6 cloudy. During the same period in 1939, 47 days were fair or mostly fair, 35 partly cloudy, and 8 cloudy.

A list of the varieties grown follows:

	1937-'38		1938-'39
1.	Rural New Yorker No. 2	1.	S 1485
2.	S 110	2.	S 1491
3.	S 891	3.	S 1578
4.	Katahdin	4.	Katahdin
5.	Earlaine	5.	Earlaine
6.	S 43055	6.	S 43055
7.	Golden	7.	S 2135
8.	Chippewa	8.	Chippewa
9.	Triumph	9.	S 2435
10	Peachblow	10.	S 2437

Seedlings 1485, 2435 and 2437 were included in the test in 1939 for the development of early-maturing progeny. The parents of 1485 and 1491 are Triumph and Earlaine, and the parents of 2435 and 2437 are Irish Cobbler and Earlaine.

Each year the plants were tallest under the longest light period as shown in table 1 and shortest under the shortest light period. Varietal differences were pronounced. In 1938 Golden produced the

tallest plants in each of the light treatments. At the 17-hour exposure, all plants of this variety with the exception of one, reached a height of more than 200 centimeters. The different light treatments had little or no effect on the thickness of stems, as revealed in table 1, those of all healthy plants being similar in diameter.

Comparative leaf areas were determined by tracing the terminal leaflet of the fourth and fifth leaf below the first bud cluster. Eight tracings of each variety in each light treatment, were made, four from the fourth, and four from the fifth leaf. The area was then determined by measuring the tracings with a planimeter. In both years plants under the 9-hour photoperiod produced the largest terminal leaflets and under the 17-hour photoperiod the smallest leaflets. (See table 1). The size, however, varied with the variety; Chippewa having had the largest terminal leaflets both years. Some varieties produced comparatively small leaves in each of the light treatments. Very little difference was noted in the color and thickness of the leaves during the different photoperiods, but the plants grown without artificial light were the first to turn yellow and show signs of maturity.

Photoperiod had a decided influence on bud abscission in 1938. Only 62 buds developed beyond the early bud stage in the 9-hour light plot; 239 in the 11-hour; 282 in the 13-hour, and 921 in the 17-hour plot. Buds were recorded as early, until the corolla became plainly visible. Some plants dropped buds early. The smallest percentage of early dropping of buds occurred at the 17-hour photoperiod. Jones and Borthwick (1) found that flower primordia are laid down at about the same stage in the development of the plant when grown with either a short or a long photoperiod. Although the photoperiod may not influence the formation of flower primordia, it does have an effect on the later development of the buds and flowers, as indicated by the abscission of many very young buds at the shorter photoperiods.

In order to secure the desired crosses, certain varieties were included in 1939,—replacing others used in 1938. The varieties added in 1939 had less tendency to abscise their flowers which accounts for the larger number of buds developing. That year 336, 425, 394, and 1095 buds developed at the 9-, 11-, 13- and 17-hour photoperiods, respectively.

The largest number of developing bud clusters per plant occurred in the 17-hour plots (table 1). This agrees with the results obtained by Stevenson and Clark (2) with light studies in the greenhouse at Arlington Farm, near Roslyn, Virginia, during the winter of 1932-'33. The number of bud clusters and the number of buds per cluster varied

TABLE 1.—*Average diameter of stems, area of terminal leaflets and number of bud clusters formed under different photoperiods. Ten varieties were used each year. Greeley, Colorado*

Photoperiod Hours	Diameter of Stem		Height of Plants		Area of Terminal Leaflets		Bud Clusters per Plant	
	1938	1939	1938	1939	1938	1939	1938	1939
	Mms.	Mms.	Cms.	Cms.	Sq. in.	Sq. in.	Number	Number
9	12.5	10.5	97.5	86.7	4.46	4.83	0.12	0.55
11	13.0	10.9	119.5	104.5	3.62	4.07	0.52	0.70
13	12.5	10.4	119.5	96.6	3.44	4.55	0.43	0.67
17	13.3	11.2	160.0	133.4	3.26	4.30	1.77	1.75
Difference required for significance.	0.63	0.61	8.18	7.46	—	—	0.21	0.26

considerably with the different varieties shown in tables 3 and 4. Seedling 43055 produced the largest number of bud clusters per plant in each of the light treatments for both years. In 1939 one plant of this seedling and one of Earlaine grown under the longest light exposure produced 6 bud clusters per plant. The largest number of buds per cluster was produced by Seedling 1578 in 1939.

The first blossoms opened 58 to 60 days after planting. In all plots the date of first bloom within a variety was about the same, regardless of photoperiod. The flowering period per plant depended largely upon the number of flower clusters. The length of time between the opening of the first and last blossom of a cluster varied from 5 to 10 days. The 17-hour plants produced the largest number of flower clusters and were in bloom the longest. One plant of Seedling 43055 blossomed for 51 days.

All varieties that produced pollen in the open produced pollen in the greenhouse, and some varieties, especially Triumph and Chippewa, that have failed to develop pollen in the breeding plot at Estes Park at an elevation of 7,500 feet produced pollen in the greenhouse. Although no satisfactory method has been devised for measuring the quantity of pollen, observations seem to indicate that the plants grown in the greenhouse produced a much larger amount of pollen than is normally produced in the field.

In 1939 the percentage of stainable pollen of the individual plants was determined by taking the pollen from one anther of five different blossoms whenever that number of flowers opened. All pollen counts were made from blossoms that had been open three or four days. Pollen grains of newly opened blossoms are inclined to clump making the counting more difficult. They are more mature and drier in older blossoms and separate better when placed on the slide.

The pollen from each anther was placed on a slide by holding the base of the anther securely and then tapping it gently with the tweezers to remove only a small quantity of pollen to make counting easy. A drop or two of acetocarmine was placed on the pollen, then covered and heated slightly to hasten the staining. In a few minutes the fertile grains became dark, whereas the others colored slightly or remained unstained. It is assumed that the pollen grains taking a dark stain were functional, although their viability was not checked by germination tests. The counting of a field of pollen was made comparatively easy by the use of a micrometer disk in the eyepiece of a compound microscope.

A total of 700 to 900 pollen grains were examined from each plant.

TABLE 2.—*Percentage of stainable pollen, number of buds pollinated, number and weight of seed balls produced and seed yield per plant under different photoperiods. Ten varieties used each year. Greeley, Colorado*

Photoperiod Hours	Stainable Pollen	Buds Pollinated per Plant		Seed Balls Produced per Plant		Seed Balls Produced per Plant		Seed Produced per Plant	
	1939	1938	1939	1938	1939	1938	1939	1938	1939
	Per Cent	Number	Number	Number	Number	Grams	Grams	Mgs.	Mgs.
9	56	0.70	2.90	0.13	1.64	0.47	5.46	10.2	107.4
11	68	2.05	4.18	0.28	2.23	1.03	7.61	19.8	121.6
13	69	3.17	4.13	0.55	2.07	2.18	6.35	41.6	129.0
17	66	12.35	12.35	2.52	6.15	9.42	22.05	173.4	382.5
Difference required for Significance		1.38	2.08	0.63	1.32	—	—	—	—

The pollen studies indicate that the length of the photoperiod had little effect on the percentage of stainable pollen as is shown in table 2. Some varieties produced consistently a high percentage of good pollen under all light exposures, whereas others produced a low percentage.

In 1938 all varieties except Rural New Yorker No. 2 and Peachblow produced fertile pollen. In 1939 all varieties included in the studies produced fertile pollen, except Seedling 2135 which failed to develop blossoms under any of the light treatments.

Considerable variation was observed in the amount of pollen and percentage of fertile pollen produced by the different anthers of a flower and by different flowers of the same plant.

To facilitate pollination, a method was devised which has proved very satisfactory for both the greenhouse and the field. A round cover glass was glued to a small wooden handle, one end of which was made round and slightly larger than the cover glass (Fig. 1). This method

FIG. 1.—Pollinating paddles showing pollen from one another and the entire blossom of Katahdin, Seedling 2435 and Seedling 43055. The paddle on the left contains no pollen. Pollen grains are more visible against a black background.

has many advantages over that of placing the pollen on the thumbnail. Pollen from individual anthers can be secured by placing the anther on the cover glass and gently tapping it with the tweezers. This method also facilitates the taking of notes and records without the loss of pollen.

By having the handles properly labeled it is possible to have the pollen of a number of different varieties available for use. The pollinated flower clusters were not enclosed, but the seed balls of a cluster were enclosed in a cheesecloth bag soon after they began to develop.

Varieties with sterile pollen were crossed with the fertile ones, the varieties with fertile pollen being selfed or crossed.

In 1938, 42 blossoms were pollinated in the 9-hour photoperiod plots; 159 in the 11-hour; 190 in the 13-hour; and 741 in the 17-hour plots; producing 8, 17, 27 and 151 seed balls, respectively.

Seedling 43055 produced the largest number of seed balls with each of the light treatments. With most varieties, the number of seed balls increased with the photoperiod.

In 1939, the varieties included in the test produced a larger number

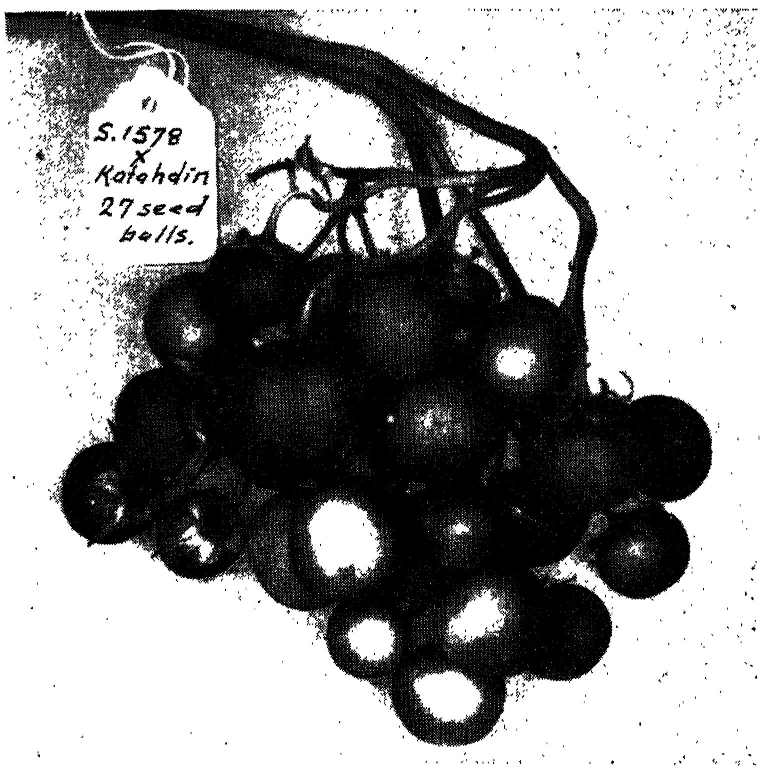

FIG. 2.—Cluster of 27 seed balls developed from 32 pollinated blossoms of Seedling 1578 in the 17-hour light exposure. This seedling also produced an abundance of seed in the 13-, 11-, and 9-hour plots.

TABLE 3.—*Differences between potato varieties as expressed in the greenhouse at Greeley, Colorado.* 1938

Variety	Diameter of Stems	Height of Plants	Area of Terminal Leaflets	Bud Clusters Formed per Plant	Buds Pollinated per Plant	Seed Balls Produced per Plant	Weight of Seed Balls Produced per Plant	Weight of Seed Produced per Plant
	Mms.	Cms.	Sq. Ins.	Number	Number	Number	Gms.	Mgs.
Golden	12.9	164.4	2.56	0.29	1.17	0.08	0.25	7.6
43055	13.4	143.2	3.39	2.00	15.92	3.50	13.06	221.6
Rural New Yorker No. 2	12.4	137.0	2.87	0.25	0.00	0.00	0.00	0.0
Peachblow	13.6	134.8	2.92	0.38	1.17	0.29	1.05	18.8
Triumph	12.8	118.9	3.32	0.54	2.38	0.17	0.70	16.0
Chippewa	12.8	117.0	7.02	1.12	9.17	0.96	6.68	124.4
Katahdin	13.8	114.9	4.53	1.29	9.62	1.88	5.99	120.9
891	12.6	109.1	2.48	0.25	0.71	0.00	0.00	0.0
110	10.8	107.3	3.63	0.25	0.67	0.04	0.19	4.9
Earlaine	13.4	94.7	4.25	0.71	6.38	1.79	4.81	98.0
Differences required for significance.	1.0	12.9	—	0.33	2.18	0.99	—	—

TABLE 4.—*Differences between potato varieties as expressed in the greenhouse at Greeley, Colorado. 1939*

Variety	Diameter of Stems	Height of Plants	Area of Terminal Leaflets	Bud Clusters Formed per Plant	Stainable Pollen	Buds Pollinated per Plant	Seed Balls Produced per Plant	Weight of Seed Balls Produced per Plant	Weight of Seed Produced per Plant
	Mms.	Cms.	Sq. Ins.	Number	Per Cent	Number	Number	Gms.	Mgs.
43055	11.5	134.5	3.56	2.25	79	15.16	7.58	33.74	541.4
1578	10.1	129.9	5.26	1.00	70	14.71	9.54	29.88	519.8
2135	10.4	119.6	3.56	0.33	—	0.00	0.00	0.00	0.0
Katahdin	12.2	114.4	3.94	0.92	75	4.79	0.75	3.42	80.5
Chippewa	11.8	104.5	6.20	0.88	22	4.00	1.00	3.02	55.8
2437	9.6	101.5	3.76	0.21	53	1.25	0.29	0.92	20.2
2435	10.2	101.2	5.61	0.88	65	4.84	2.13	6.22	129.4
1491	12.0	86.0	4.50	0.88	39	4.67	2.33	4.97	84.0
Earlaine	10.8	82.3	4.36	1.12	76	7.84	5.67	19.92	387.8
1485	9.0	79.2	3.63	0.71	76	1.67	0.79	1.59	33.6
Differences required for significance.	0.97	11.8	—	0.42	—	3.30	2.09	—	—

of flowers and seed balls per plant in each of the light treatments than were produced by the varieties grown the previous year (tables 3 and 4). In that year, 174 flowers were pollinated in the 9-hour plot; 251 in the 11-hour; 248 in the 13-hour; and 742 in the 17-hour plot; producing 98, 134, 121 and 369 seed balls, respectively.

Most of the varieties produced the largest number of seed balls in the 17-hour plot. A large percentage of all pollinated blossoms in each of the light treatments produced seed each year the studies were conducted. In 1939, 56 per cent of all pollinated blossoms in the 9-hour plots produced seed balls; 53 per cent in the 11-hour; 49 per cent in the 13-hour; and 50 per cent in the 17-hour plots.

It is quite evident that varieties differ in their light requirements for flower and seed production. However, most varieties included in the test produced the largest number of seed balls per plant with the longer light periods. Under greenhouse conditions at Beltsville, Maryland, Clarke and Lombard (3) found a larger number of flowers and seed balls were produced with the longer photoperiod. In general, 16 hours appeared to be optimum at Beltsville for both flowering and fruiting. At Greeley, Seedling 1578 produced an abundance of seed balls with each light treatment. However, the largest number, 17.5 seed balls per plant, developed at the longest light period (Fig. 2). Varieties

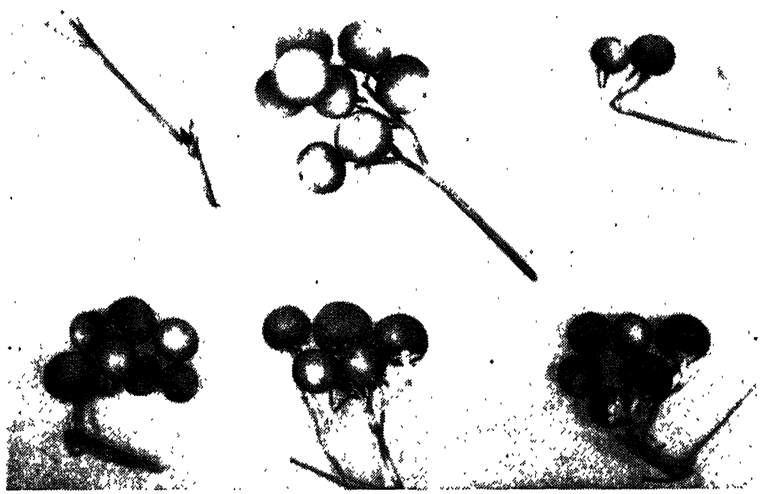

FIG. 3.—Seed balls from one plant of Earlaine grown in a 17-hour day. This plant produced 6 bud clusters. Forty-six blossoms were pollinated, producing 29 seed balls and 1,624 milligrams of seed.

that produced the largest number of seed balls also produced the most seed per plant as revealed in tables 3 and 4. The heaviest yield of seed per plant was produced by Earlaine in 1939 under a 17-hour photoperiod (Fig. 3), whereas none was produced by this variety at the 9-hour photoperiod.

Seedling 43055 produced the largest number of bud clusters and the most seed each year. Katahdin and Chippewa produced plants similar in height, number of bud clusters per plant, and weight of seed balls per plant. Katahdin, however, produced more seed in 1939 than did Chippewa.

Earlaine produced the smallest plants of any of the varieties in 1938 and correspondingly small ones in 1939. This variety, however, produced a large number of blossoms and seed balls, producing 387.8 milligrams of seed per plant in 1939.

Rural New Yorker No. 2 was the only variety that failed to produce blossoms in 1938 and only one variety in the test, Seedling 2135, failed to produce blossoms in 1939. All varieties included in the test produced fertile pollen except Rural New Yorker No. 2 and Peachblow, Triumph producing the smallest amount of fertile pollen.

Summary

Results of the studies conducted with 9-, 11-, 13-, and 17-hour photoperiods in the greenhouse indicate that the different photoperiods have little effect on the diameter of the stems in the potato plants. There was, however, a significant difference in the height of the plants,—the tallest plants being produced with the longest light period. There was a highly significant difference in the number of bud clusters produced per plant by the 17-hour and all the remaining treatments. The different photoperiods had no effect on the percentage of fertile or stainable pollen. The plants in the 17-hour photoperiod produced the most buds for pollination and developed the most seed balls and the largest weight of both seed balls and seed.

The results of the two-year studies indicate that varieties differ widely in their light requirements for flower and seed production. Some varieties produced an abundance of blossoms and seed with each of the light treatments; however, most varieties developed a larger number of blossoms and more seed with the longest photoperiod.

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A REVIEW OF ENTOMOLOGICAL RESEARCH ON POTATO INSECTS

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This paper is a summary of recent entomological research on potato insects, their life histories, ecological relationships and economic control. Leaf-feeding insects recently mentioned in the literature included the Colorado potato beetle, potato flea beetles, leafhoppers and potato psyllids. Wireworms have received considerable attention during the past year as is evident from the large number of articles published on their bionomics and control. The rôle of insects in the dissemination of seed-piece decay organisms and virus diseases has been the object of some investigations, the results of which have been recorded in several very excellent papers.

A new potato pest was reported from Colorado (9, 10) as the pentatomid, *Chrocochroa sayi,* commonly referred to as Say's plant bug. The feeding of the adults caused either a wilt of the tip leaves or a curl followed by reddish coloration along the leaf margins. All the tubers were indirectly affected by the injury to the foliage and grew malformed or knobby. From the description, the injury appears to be similar to the wilt caused by the tarnished plant bug, *Lygus pratensis.*

Bonde (6), Reid (24) and co-workers (23) studied the relation of Anthomyid maggots to the dissemination of seed-piece decay and blackleg organisms. The seed corn maggot, *Hylemyia cilicrura* Rond and the potato seed maggot, *Hylemyia trichodactyla* Rond. were found to be abundant in seed pieces soon after sprout appearance. The flies laid their eggs near the set and the maggots upon emergence were attracted to the decayed lesions which always form on cut surfaces of unsuberized seed. These maggots then invaded the seed pieces spreading the decay and causing a rapid breakdown of the mother tubers.

Properly suberized seed resisted decay and was unattractive to the Anthomyid maggots. A number of field tests showed further that significant increases in tuber yields were obtained by the prevention of maggot damage and seed piece decay through the use of cured seed.

A common pest, although one of minor importance on potatoes, is the European corn borer, *Pyrausta nubilalis* Huber, a stalk-boring insect. The borer feeds inside of the stem causing a wilt and death of the vines. Beard (5) investigated the damage as reflected in reduction of tuber yield and reported no conclusive evidence that borer damage decreased the yield.

One of our most familiar potato pests, the Colorado potato beetle, *Leptinotarsa decemlineata* Say, has been subject to extensive entomological research in Europe since its introduction from America in 1918. In this country the potato beetle is considered chiefly a nuisance because control measures have become a matter of routine practice with most growers. However, in Europe, due to the lack of proper facilities for control the Colorado potato beetle is a threat to the potato crop, a vital source of food in most central European countries. Apparently it continues to spread (3) although accounts of its progress are meager at this time. The food habits of the beetle have been studied (8) as a guide to the breeding of potato stocks immune to attack. The present host range as shown by Brues (7) remains restricted to the original host, the cocklebur, and to the potato and eggplant.

Some of the other foliage insects are more important to potato growers in this country and spraying and dusting for the control of these pests has become a necessity. Life histories have been studied and discussed for potato fleabeetles, *Epitrix cucumeris* (26, 30), the eastern potato leafhopper, *Empoasca fabae* (11), the western potato leafhopper, *Empoasca abrupta* DeL. and potato psyllids, *Paratrioza cockerelli* Sulc. (13, 26). Ecological studies of the flea beetle in the muckland region of western New York have been published by Wolfenbarger (32) who considered that the hibernation quarters were in uncultivated areas near potato fields.

Reports of results on protecting potatoes from attacks by the various leaf-feeding insects are voluminous and the spray or dust schedules are extremely variable. Sprays and dusts used successfully against flea beetles are Bordeaux mixture, arsenicals and rotenone-bearing materials (12, 18, 26, 30); against leafhoppers, Bordeaux, sulfur and pyrethrum (2, 11, 12, 13, 18); and against psyllids, sulfur in various forms (13, 26).

The breeding of resistant or immune potato varieties to insect attack is receiving more attention from the plant breeders and entomologists. Sleesman (31) studied the resistance to leafhoppers and flea beetles of a number of Solanum species used as breeding stock. Certain species, notably *Solanum polyadenium,* showed marked resistance as indicated by natural infestation and ability of the insects to survive on the foliage. Allen *et al* (1) noted that late-maturing varieties were not so subject to hopperburn as early sorts but did not consider maturity as the prime factor in susceptibility.

The only tuber pest of prominence recorded in the recent literature was the wireworm, larva of the Elaterid or click beetle. One of the outstanding contributions has been the review of wireworm control by Thomas (27) who has brought together and summarized the literature to the present time. Crop rotation seems to be the predominate line of approach to control. In England where a campaign to increase the arable land is part of the war effort, the farmers have been advised to avoid planting wireworm-susceptible crops for three years after breaking up grasslands (4). The wireworms concerned are similar in habits to the wheat wireworm, *Agriotes mancus* Say, a pest of great importance in many eastern states. The wheat wireworm breeds almost exclusively in sod or grassland (22) and potatoes commonly follow these crops in the rotation. Elimination of the sod crops in the rotation reduced infestation and the resultant injury. In the prairie country, the prairie grain wireworm, *Cormbytes* sp., may be effectively controlled according to Munro (19) by clean summer fallow previous to planting potatoes or grain. In South Carolina (20) the control program involves the use of resistant crops, land-resting and increased soil fertility.

In some instances suitable crop rotations or cropping practices can not be used effectively and artificial control methods have been substituted. However, soil insecticides are expensive and difficult to use, hence this phase of control has been neglected. The use of dichloroethyl-ether has shown promise on vegetable crops (21) but its use is restricted at present.

A few contributions on the rôle of insects as vectors of virus diseases and related problems have been made recently. Roberts (25) studied the feeding punctures of aphids to determine the rate of penetration, the plant tissues involved and virus infection. Observations on vector migrations have been made (15, 28) and interesting results obtained on the diffusion of the insects into the fields.

The part played by insects in transmitting and disseminating plant

diseases has been at last reviewed in an interesting text by Leach (17) entitled, "Insect Transmission of Plant Diseases." This important subject is fully discussed and in an interesting manner.

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SECTIONAL NOTES

CALIFORNIA

The potato crop of Kern County is now completely planted, with the exception of the late area which is in the mountains. At the present time there are approximately 28,000 acres of potatoes planted which will be harvested between now and the 20th of July. Wind storms have damaged the crop in the early section, which will cause in a lighter yield. Rains have caused later planting in the Wasco area, and will probably result in heavy harvesting during the latter part of June and the early part of July.

A new area is being developed in one of the adjacent counties by growers in this county. This is Santa Barbara. There were about 1000 acres in this area last year, and this year by the time planting is completed in that area, there will possibly be 2500 acres. It is an area that may develop into 10,000 to approximately 15,000 acres. (April 7).—M. A. Lindsay.

Including the 6th of April, the shipments from Edison this season totaled 104 cars compared with 166 at the same date last year. The market opened on the 29th of March at $2.50 but declined quite rapidly to a basis of $1.60 at which figure the market closed last night.

The yields from the early-planted crops are very disappointing,

showing an average of approximately 125 sacks to the acre. This light yield was caused by the excessive rainfall and wind damage which the district experienced this year.

Although the acreage in the Edison District is considerably larger than last season, we do not believe that the actual tonnage will exceed last year's figures for the reasons mentioned.

The best demand so far for the Early Edison potatoes has come from the northwest. The Eastern Markets have been slow to come in on account of the great difference between the price of these potatoes plus transportation charges and the values of old potatoes. (April 10). —E. MARX.

IDAHO

It is a little early to make a very close estimate concerning the potato prospects in Idaho for 1941, but our statistician now anticipates that the acreage will be eight or ten per cent less than last year. Our prospects of water in some parts of the state are not so good as we might wish, hence, my guess is that we will have fewer potatoes in Idaho in 1941 than in 1940. In fact, this is a pretty safe estimate in that last year our yields were, I believe, the highest on record.

Our un-irrigated lands were sufficiently wet during the latter part of the growing season, and the frosts held off so that when the snow fell in the middle of November, the vines were still green.

At present, potatoes are selling for a little more than they were the early part of the season, and this may help to stimulate planting, although it probably will not affect the acreage to any extent.

We have plenty of good seed, that is seed of our standard variety, the Netted Gem, I also expect as much seed of the Bliss variety as will be needed for our early planting. However, there may be considerable change in the attitude toward potato growing between now and our normal planting time which is generally from the middle of May to the latter part of June.

Our main crop, when planted early, is difficult to pull through without a high percentage of number two potatoes. Therefore there are tendencies to plant so that tuber formation will occur after the excessive heat of mid-summer. (April 9).—E. R. BENNETT.

IOWA

Storage facilities have rapidly increased in Iowa during the past five years; in fact, more rapidly than knowledge of the economics of sale.

The 1940 crop in the nation was somewhat in excess of needs, and much of that excescs in the Red River valley, in Idaho and in the western Triumph regions, all tending to unload in this region.

Despite repeated warnings by the undersigned and by Daniel Dean, who was with us in December, that the past winter was not favorable for the use of the fine new storage, many growers stored. They will apparently clear up, but possibly at fall prices. A little rally in certified seed prices has helped the sale of first year Cobblers from P. E. I. stock. One grower grew and harvested 400 acres without discovering any visible virus diseases.

Appropriations for the breeding of potatoes have passed Congress; and our onion breeding appropriations have been doubled.

We are using state money to provide Stevenson and Clark with five acres of our best land for large scale trials of early seedlings. (April)—C. L. Fitch.

OREGON

The feed diversion program is now in effect with approximately 250 cars diverted, to date, with additional applications for a like amount.

Our season shipments have passed the 8,000 mark with another 1,000 or 1,500 to be shipped about the 1st of April. The interest of our growers indicates considerable increase in acreage of certified White Rose with approximately the same acreage of certified Russets.

The general acreage, we believe, will be slightly less than that of last year. (April 3).—A. A. Henderson.

SOUTH CAROLINA

South Carolina potatoes were planted during the first part of February, as usual, but the low temperatures during February and March retarded emergence from ten days to two weeks. The temperatures averaged 7° below normal for February and were below normal during March, so it was not surprising that sprouts were emerging during the latter part of March instead of the first week in that month.

The stands on most farms are good and the crop is growing rapidly at the present time. There has been an abundance of rain during the past month. Some fields were flooded with salt water during the hurricane of last year but the recent rains have probably washed out much of the salt that remained.

The acreage of potatoes in the state this season is slightly larger than that of last year. As in former years the Irish Cobbler is the leading variety but there has been an increase in the acreage of White Rose and Bliss Triumph. Growers are showing much more interest

in potato varieties as is shown by the fact that some of them are making trial plantings of the newer varieties such as Sebago, Pontiac, and Katahdin. In tests at the Truck Experiment Station, Katahdin, Sequoia, and Houma have been among the best from the standpoint of yields and general adaptation to local conditions.

Present indications show that practically all of the crop will be shipped in bags this year, although some early Bliss Triumphs and Irish Cobblers may be packed in tubs. The old 11-peck wooden barrel will be found only in the better class antique shops and museums—if at all! (April 8).—MITCHELL JENKINS, JR.

VIRGINIA

The acreage on the Eastern Shore of Virginia is somewhat larger than it was last year. The low price of seed and the abundant supply of home seed, with somewhat lower prices for fertilizer, probably led to this increased planting. Again, the potato grower is always an optimistic soul in the spring; he can always figure out some way of deceiving himself to the extent that he believes the crop will be profitable. No doubt the war situation convinced many people that higher prices would prevail this year. We sincerely hope that this will be true. I can not tell how much the acreage increase will amount to, but probably it will not be less than 5 per cent and possibly 10 per cent.

The initial plantings were somewhat earlier than usual, and possibly the last plantings were completed earlier than they usually are, but notwithstanding that condition, the average planting time on the Eastern Shore was later than normal, because of the cold, wet weather. We understand the same thing is true in the Carolinas. Again, the low temperatures prevented rapid germination and development of the potato plants. Later on there were exceedingly heavy rains which flooded some of the low lands and caused other lands to become exceedingly wet. There was some decay from this cause, but it is impossible to tell the extent of the loss. This can be determined only after the plants have emerged above ground.

At this time we can not tell anything about our crop, but it seems safe to predict that the season of harvest may be somewhat delayed, that there is the expectation that our crop will overlap with the northern half of North Carolina, and it is also safe to say that there has been some loss of acreage caused by decay. This reputed loss is usually exaggerated, and we would not expect it to reduce the acreage to any great extent. (April 15).—G. S. RALSTON.

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THE INFLUENCE OF CERTAIN CULTURAL PRACTICES AND DISEASE CONTROL ON YIELD OF POTATOES[1]

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Introduction

In 1938, an experiment was conducted to determine the influence of certain cultural practices on the incidence of potato blue stem, a disease of unknown cause (1, 2). Unfortunately an epidemic of late blight killed the plants before blue stem had appeared in amounts sufficient to yield the information desired. Although the primary purpose of the experiment was not achieved, the plot arrangement permitted a satisfactory study of the influence of cultural practices and disease control on yield. The results are presented, even though based on data from a single season, (1) because they add to our scanty knowledge of the interaction of cultural practices, and (2) because the methods used illustrate an efficient design of a complex field experiment.

It is generally recognized that the effect of a particular cultural factor may depend upon whatever additional factors are present. In

[1]Published, with the approval of the Director of West Virginia Agricultural Experiment Station, as Scientific Paper No. 233.

[2]Died May 8, 1939. This paper is based on data accumulated by Mr. Hill in the summer of 1938. Credit for the design of the experiment is due to Dr. W. J. Youden, who helped Mr. Hill plan the experiment while the latter was a guest worker at the Boyce Thompson Institute for Plant Research. The statistical computations were made by Dr. C. F. Taylor of the Department of Plant Pathology and Bacteriology of West Virginia University and by Dr. Youden, who also contributed much toward the preparation of the manuscript.

spite of this, many yield trials are limited to a simple contrast of a few alternative choices. The reason for this limitation is obvious. A complex experiment involving several factors, some of which may be set at two or more levels of application, results in a large number of different treatments. In the well established procedure of replicated blocks each block must contain all the treatments. The result, therefore, is a block so large that the presumption of relative uniformity of soil within the block is not justified. If such an experiment is attempted, the errors caused by this lack of homogeneity will defeat the purpose of the project. Consequently, in spite of the disadvantage of severely restricting the scope of the experiment, it is wise to use small blocks in order to obtain reliable results.

Recently much progress has been made in the direction of retaining both the advantage of a comprehensive experiment and the precision associated with small blocks. Yates (3, 4, 5, 6) has described experimental designs which satisfy both requirements. There are special opportunities in the case of factorial experiments, *i. e.*, experiments in which all possible combinations of a number of factors are tested. In this work it was desired to study three dates of planting, the advantage of certified seed compared with seed one crop removed from certification, the effect of fertilizer, and finally to compare three different sprays and an unsprayed control. The number of combinations of

3 Dates x 2 Seeds x 2 Fertilizers x 4 Sprays

is 48. Consequently, with a unit plot of any great size, the total of 48 forms a large, unwieldy block. If the experiment had consisted of only the three different dates of planting and if these had been run in triplicate then nine plots would have been required. These could have been arranged in three blocks of three plots each, or in a Latin Square. Inasmuch as the date of planting was expected to have a pronounced effect it would not matter if these plots were quite large or if very few degrees of freedom were available for the estimate of error. Each of these whole plots could now be subdivided into four plots to which the four combinations of seeds and fertilizer could be assigned. This device is known as a split-plot experiment. One complication arises in that some of the comparisons are known more accurately than others, it being evident that the seeds and fertilizer are compared in plots which are in close proximity. Success depends upon assigning the most important factors, or those with small effects, to the more accurate portion of the experiment.

TABLE 1.—*Code numbers assigned to treatments*

	Bordeaux Mixture 4-4-50	Bordeaux Plus Calcium Arsenate 4-4-2-50	Bordeaux Plus Nicotine Sulphate 4-4-½-50	Check
Certified seed and fertilizer	11	12	13	14
1 year removed from certified seed—no fertilizer	21	22	23	24
1 year removed from certified seed—fertilizer	31	32	33	34
Certified seed—no fertilizer	41	42	43	44

In this experiment the four sprays were applied to further subdivisions of the plots. That is, each of the 36 plots was subdivided to receive all four sprays, making a total of 144 sub plots. These subplots introduce a third estimate of error which is applicable to comparisons between sprays. This type of experiment does require that more care be taken in examining the tables, since comparisons within a row will be subject to a different error from that applying within a column. Aside from convenience, however, there is no objection to the different factors having different errors; on the contrary, it is an advantage to insure that the most important factor has the least error.

DESCRIPTION OF THE EXPERIMENT

A field 450 by 120 feet was divided into nine whole plots each 150 by 40 feet. Three of these were planted on the 27th of April; three on the 25th of May, and three on the 6th of June. The whole plots were then subdivided into four strips or plots ten feet wide. An application of 5-10-10 fertilizer at the rate of 1400 pounds per acre was made to two of the strips in each whole plot. Certified seed (smooth rural, obtained from Mr. Hollenbeck, Tulby, New York) was planted in one fertilized strip and one unfertilized strip in each whole plot. The two remaining strips were planted with seed obtained from the same source the previous year and grown locally in 1937. Each of the 36 strips was divided into fourths for the spray applications. The sub-plots for sprays were four rows wide (the rows being 30 inches apart) and 37.5 feet long.

Since these seed stocks were stored during the early part of the winter under different conditions, factors other than certification may have influenced the differences in yield. However, since no appreciable storage injury was noted, certification is believed to have been the most important factor.

TABLE 2.—*Chart showing location of treatments (Code numbers in brackets) and yields of potatoes in bushels per acre*

(34)	70	(32)	70	(33)	55	(31)	43	(23)	15	(21)	18	(24)	6	(22)	25	(32)	45	(33)	39	(31)	36	(34)	15
(41)	95	(44)	56 I	(43)	81	(42)	73	(12)	16	(14)	8 III	(13)	20	(11)	35	(41)	108	(44)	21 II	(42)	83	(43)	50
(24)	20	(21)	23	(23)	31	(22)	45	(41)	15	(44)	6	(42)	26	(43)	28	(21)	46	(23)	30	(22)	33	(24)	18
(12)	211	(11)	173	(14)	118	(13)	162	(32)	41	(34)	13	(33)	46	(31)	41	(14)	33	(13)	118	(12)	110	(11)	95
(42)	61	(43)	45	(44)	13	(41)	73	(44)	40	(42)	160	(43)	107	(41)	130	(34)	15	(33)	55	(32)	26	(31)	28
(34)	11	(33)	26 II	(31)	33	(32)	41	(31)	60	(34)	91 I	(33)	78	(32)	60	(43)	28	(41)	18 III	(44)	6	(42)	26
(24)	3	(21)	23	(22)	33	(23)	30	(11)	180	(12)	303	(14)	125	(13)	206	(23)	30	(21)	21	(22)	22	(24)	10
(14)	30	(11)	121	(12)	83	(13)	96	(22)	76	(23)	61	(21)	76	(24)	46	(13)	50	(11)	46	(12)	50	(14)	8
(13)	31	(14)	5	(11)	21	(12)	36	(23)	55	(22)	60	(21)	50	(24)	20	(43)	138	(41)	163	(44)	100	(42)	146
(23)	18	(21)	26 III	(24)	3	(22)	30	(34)	25	(32)	65 II	(33)	75	(31)	70	(13)	188	(14)	121 I	(11)	185	(12)	201
(42)	66	(41)	41	(44)	3	(43)	23	(13)	131	(11)	168	(12)	135	(14)	40	(22)	83	(24)	82	(21)	75	(23)	70
(32)	35	(31)	30	(33)	26	(34)	8	(43)	50	(44)	33	(42)	65	(41)	56	(32)	103	(33)	96	(34)	75	(31)	100

For convenience in identification a simple code number system was used to label the 16 combinations of seed, fertilizer, and spray. These code numbers are shown in table 1, which also shows the composition of the three sprays. The plots planted on the 27th of April received ten applications; the intermediate date, nine applications; and the last planted, seven applications. The spray was applied with a compressed-air sprayer (pressure between 25-50 pounds) similar to those in general use for small fields of potatoes grown in West Virginia.

The arrangement of the treatments in the field is random, subject to restrictions mentioned earlier and is shown in table 2. The numbers in brackets are the code numbers assigned in table 1. The associated figures show the sub-plot yields converted to bushels per acre. The Roman numerals in each one-ninth of the field refer to the successive dates of planting. Mimeographed copies of the chart were found useful as a guide in planting, in recording observations during the growing season, and for entering the yields when the potatoes were harvested.

Observations on the Incidence of Disease

Late blight was observed on the 15th of July and by the 20th of July infection was severe on the non-sprayed plots. This served as a source of infection for the remaining plots in the field. From mid-July until the 25th of August, heavy, dashing rains reduced the effectiveness of the spray applications. By the 30th of August, all plants were dead except in the sprayed plots of the third planting date. (Commercial potato fields in this section were killed by late blight by the 30th of July).

Blue stem was first observed on the early planting on the 22d of July. By the 1st of August (95 days after planting) 0.5 per cent of the plants in the first-planted plots showed blue-stem symptoms. On the 10th of August, one per cent of the plants from the second planting showed blue-stem symptoms (77 days after planting); whereas four per cent of the plants from the last planting were affected. Late blight prevented the obtaining of further data on the incidence of blue stem.

Discussion of the Yield Data

The striking effect that time of planting has on the yield is exhibited in table 3. In this table the entries are the average yields of the 16 sub-plots which were planted together at the same time. The Roman numerals refer to the planting date and the data are set down in

TABLE 3.—*Average yields in bushels per acre of whole plots*

I 82.9	III 22.4	II 55.0	53.4
II 45.1	I 112.4	III 27.4	61.7
III 25.1	II 68.6	I 120.4	71.4
51.0	67.8	67.6	

Roman numerals refer to time of planting

the same order as the planting in the field. The averages at the right and bottom of the table show the average yield for each one-third of the field which contains all three planting dates. These columnar averages furnish information on the uniformity of the experimental area. The progressive increase from left to right and from top to bottom reveals a rather steep gradient in fertility from the south corner of the field to the north corner. The disposition of the areas planted at different dates equalizes in large degree this trend in fertility. The average yields for the three planting dates are:

April 27	May 25	June 6
105.2	56.3	25.0 bushels per acre

The analysis of variance for dates of planting is as follows:

	D.F.	Sum of Squares	Mean Square
Rows	2	7739.6	3869.8
Columns	2	8901.3	4450.7
Dates	2	156995.9	78498.0
Error	2	512.0	256.0 sub plot basis
	8	174148.8	

With only two degrees of freedom the estimate of error is subject to considerable uncertainty and, as will appear later, is apparently under-estimated in this case. The mean square for the dates is about 300 times as large as the error mean square and confirms the conclusion derived from inspecting the average yields for these three dates.

Within any whole plot there were four plots planted with the four combinations of seed and fertilizer. Combining the results of the whole experiment the average yields for these four combinations are as follows:

	Certified Seed	Non-certified Seed	Average
Fertilizer	101.6	48.5	75.1
No fertilizer	62.0	36.5	49.3
Average	81.8	42.5	

It appears that on the average the application of fertilizer increased the yield about 50 per cent whereas the yield was nearly doubled by the use of certified seed in place of seed one year removed from certification. It is desirable to examine the figures more closely to discover whether the added fertilizer brought about the same proportionate increase with non-certified seeds as with the certified lot. The figures show that in the first case the yield was increased one-third; in the latter case nearly two-thirds, the absolute gains being 12 to 40 bushels. Or stated another way, the use of certified seed in place of non-certified seed in fertilized soil more than doubled the yield, but fell considerably short of this gain where unfertilized soil was employed. From either approach there is strong evidence that in order to get the full benefit from either fertilizer or certified seeds, both should be employed. This particular point is established with high odds in the item for the interaction of seeds and fertilizer in the analysis of variance for this section of the experiment.

All the interactions in this part of the analysis are established with satisfactory significance and direct attention to the various individual combinations of seed, fertilizer, and time of planting. Table 4 shows in the second and third columns the contrast in average yields for all plots

ANALYSIS OF VARIANCE OF PLOTS

(Subplot basis)

Item	D. F.	Sum of Squares	Mean Square
Whole plots	8	174148.8	
Fertilizer	1	23999.2	23999.2
Seeds	1	55735.3	55735.3
Fert. x Seeds	1	6847.6	6847.6
Fert. x Dates	2	8803.6	4401.8
Seeds x Dates	2	35614.7	17807.3
Fert. x Seeds x Dates	2	6450.9	3225.4
Error	18	9148.5	508.3
Plots	35	320748.6	

TABLE 4.—*Average yields in bushels per acre for different planting dates*

Date of Planting 1938	Seeds (All Plots)		Fertilizer (All Plots)	
	Certified	Non-Certified	5-10-10	None
April 22	144.3	66.2	128.1	82.4
May 25	75.8	30.8	64.4	44.1
June 5	25.5	24.5	28.8	21.3

for the two seeds for each of the three dates. It is apparent that under these conditions, a late planting virtually nullifies the advantage that might have been obtained from using certified seed. Similarly in the fourth and fifth columns it appears that fertilizer is very nearly wasted on a late planting in comparison with the effect on early planting. This point is verified in table 5 which shows the response for each combina-

TABLE 5.—*Average yields for different dates and combinations of seed and fertilizer. Bushels per acre*

Date of Planting	Certified Seed		Non-Certified Seed	
	Fert.	No Fert.	Fert.	No Fert.
April 27	181.1	107.4	75.1	57.3
May 25	96.7	54.8	40.1	33.4
June 6	27.2	23.8	30.3	18.7

tion of seed and fertilizer for each date. The figures at the four corners of the table show that the aggregate gain from the use of good seed and fertilizer is enormously enhanced by an early planting. That is, 181.1 is more than threefold 57.3, whereas 27.2 is only 50 per cent larger than 18.7.

The importance of spraying potatoes is demonstrated by the fact that the average yield of all sprayed plots is nearly twice that of the control or unsprayed plots.

The averages for the individual sprays are as follows:

Bordeaux	Bordeaux Plus Arsenate	Bordeaux Plus Nicotine	Check Unsprayed
70.1	76.2	66.3	36.0

The statistical analysis for the subplots yields an estimate of error of 14.5 bushels per acre for a single subplot. The above figures are the averages of 36 subplots and consequently the standard error of these averages is 2.4 bushels. The minimum significant differences is therefore 2.2, 2.4, or 6.8 bushels. The conclusion follows that under these circumstances calcium arsenate was superior to nicotine sulphate as an addition to the Bordeaux mixture. The analysis of variance for subplots follows:

ANALYSIS OF VARIANCE FOR SUBPLOTS

Item	D. F.	Sum of Squares	Mean Square
Plots	35	320748.6	11524.8
Sprays	3	34574.3	788.6
Sprays x Date	6	4731.8	426.9
Sprays x Fert.	3	1280.7	3082.9
Sprays x Seeds	3	9248.6	322.6
Sprays x Dates x Fert.	6	1935.4	845.7
Sprays x Dates x Seeds	6	5074.0	354.6
Sprays x Fert. x Seeds	3	1063.7	408.1
Sprays x Fert. x Seeds x Date.	6	2448.5	
Error	72	15063.7	
Subplots	143	396169.3	

The most important interaction of sprays is with the choice of seed. The second and third columns of table 6 show that both the relative and absolute gain due to spraying is much larger for certified than uncertified seeds. The last three columns of the table show that the net increase arising from spraying is larger for the earlier plantings. The interaction of sprays with fertilizer is not significant. The interaction of sprays, seeds, and dates indicates that not only does spraying give a greater return when certified seeds are used, but that the increased

TABLE 6.—*Average yields in bushels per acre obtained with the different sprays*

Spray	Seed (All Plots)		Date (All Plots)		
	Certified	Non-Certified	April 27	May 25	June 6
Bordeaux	95.7	44.4	108.6	73.3	28.3
Bordeaux plus arsenate	102.8	49.6	127.6	67.8	33.3
Bordeaux plus nicotine	86.2	46.4	106.1	62.1	30.8
Unsprayed check	42.6	29.5	78.7	21.8	7.6

TABLE 7.—*Average yields for all combinations of seeds, sprays, and planting dates. Bushels per acre*

Date	Seed Certified	Bordeaux	Bordeaux Arsenate	Bordeaux Nicotine	Check Unsprayed
April 27	Yes	154.3	182.3	147.0	93.3
	No	62.8	72.8	65.2	64.0
May 25	Yes	103.5	89.5	81.7	28.3
	No	43.0	46.2	42.5	15.3
June 6	Yes	29.3	36.7	30.0	6.0
	No	27.3	29.8	31.7	9.2

return from spraying certified seeds is more pronounced with the early plantings. This may be deduced from an examination of table 7.

The statistical analysis of these data shows that comparisons of yields of subplots within the same plot are more accurate than between sub-plots from different plots; the mean squares being 209 and 508 respectively. The rather small differences in effectiveness of the different sprays is a strong argument for the use in this experiment of a field layout which gives a minimum error to the spray comparisons even at the expense of other factors. It is interesting to note that the interactions are judged by the least of the errors of the factors involved. For example, we may wish to contrast the gain due to a Bordeaux spray with certified seeds with the increase for non-certified seeds. The respective gains (see table 6) are:

$$95.7-42.6=53.1$$
$$\text{and } 44.4-29.5=14.9$$

The difference between these increases is 38.2. The subplots involved are from different plots but examination shows that the values 53.1 and 14.9 are obtained by taking differences between subplots within the same plot.

The error mean square for subplots from different whole plots would naturally be expected to exceed both the other estimates of error. Only two degrees of freedom are available for this estimate and by chance an unusually low value was obtained. The yields for the different planting times are still significant even if the contribution of rows and columns of the Latin Square are included in the error mean square.

SUMMARY

A trial was conducted with potatoes to determine the value of certain cultural practices such as time of planting, the use of fertilizer, of certified seed, and of various sprays on the incidence of blue stem and on yield. Premature death of plants, caused by late blight, resulted in the loss of much desired data on the effect of cultural practices on development of blue stem.

The heavy infestation of late blight provided data on the beneficial effect of sprays on yield. All the sprays tested increased the yield of potatoes greatly. The combination of calcium arsenate and Bordeaux mixture was found superior to Bordeaux and nicotine sulphate.

It is evident that if the individual cultural factors had been studied in separate experiments, the benefits resulting from early planting, certified seed, fertilizer, and Bordeaux sprays would have been unquestionably established. It would by no means be clear, however, whether the gains associated wifh the individual factors were in themselves a true indication of the potentialities of the crop under various combinations of cultural practices. The results of this complex experiment demonstrate that having provided a favorable condition in respect to the study of one factor, it would be unwise to ignore or skimp other factors. On the contrarv an adequate return on the investment made for certified seeds or fertilizer really depends upon due provision being made for early planting and spraying.

All the sprays tested greatly increased the yield of potatoes. The combination of calcium arsenate and Bordeaux mixture was found superior to Bordeaux and nicotine sulphate.

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A METHOD FOR THE DETERMINATION OF LOSSES DUE TO DISEASED OR MISSING PLANTS

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Stewart (1919 and 1921) and later Livermore (1927) have shown that with potatoes the adjacent hills on either side of a missing hill make up about one-fourth of the loss in yield of single missing hills or together the hills on both sides offset about a half of the loss. This naturally raised the question as to whether the low yield of a potato plant affected with a virus disease may not in part be made up by adjacent healthy hills. It is obvious that the situation would vary with changes in the percentage of diseased or missing hills.

Following a suggestion by Dr. K. H. Fernow that the hills in a potato field could be grouped into a few classes as regards the effect of adjacent hills, it is evident that an estimate could be made of the loss in yield for any percentage of diseased or missing plants if the yield of the central hills in these different classes were determined and if the frequency of such different classes of hills could be estimated for any percentage of disease.

The hills in a field could be classified as to whether they were healthy or diseased and as to whether they were bordered on one or both sides by healthy or diseased hills. Thus if we write H for healthy and D for a particular disease being studied and consider the central hill in a series of three as the only one being classified, we could make the following classes: HHH, DHD, DHH, HHD, DDD, HDH, HDD and DDH. Among these, there are two pairs, each of which might be combined into a single class, thus DHH and HHD only differ as to whether the diseased plant is on one side or the other of the central plant, the yield of which is to be considered. Similarly HDD and DDH might be combined. Thus the total number of classes is reduced to six.

The estimation of the number of plants, situated as the central plant in these classes may be illustrated by the case of a field with 10 per cent diseased plants. Take the DHD class. The chance of getting the first D by a random sampling is 1 in 10 or 1/10, the H is 9/10 and the last D is 1/10. The chance of getting this series is then the product of these numbers of $1/10 \cdot 9/10 \cdot 1/10 = 9/1000 = .9$ per cent. Similarly the chances of obtaining the other classes are illustrated in the following table.

Expected frequency of classes in a field with 10 per cent disease.
Classes

$$
\begin{array}{llll}
\text{HHH} & = 9/10 \,.\, 9/10 \,.\, 9/10 & = 729/1000 = & 72.9 \text{ per cent} \\
\text{DHD} & = 1/10 \,.\, 9/10 \,.\, 1/10 & = \quad 9/1000 = & .9 \text{ per cent} \\
\left.\begin{array}{l}\text{DHH} \\ \text{HHD}\end{array}\right\} & = 9/10 \,.\, 9/10 \,.\, 1/10 \,.\, 2 & = 162/1000 = & 16.2 \text{ per cent} \\
\text{DDD} & = 1/10 \,.\, 1/10 \,.\, 1/10 & = \quad 1/1000 = & 0.1 \text{ per cent} \\
\text{HDH} & = 9/10 \,.\, 1/10 \,.\, 9/10 & = \quad 81/1000 = & 8.1 \text{ per cent} \\
\left.\begin{array}{l}\text{HDD} \\ \text{DDH}\end{array}\right\} & = 9/10 \,.\, 1/10 \,.\, 1/10 \,.\, 2 & = \quad 18/1000 = & 100.0/1.8 \text{ per cent}
\end{array}
$$

Similarly the percentage of plants in a field similar to the central plants in the above classes may be estimated for other percentages of disease as has been done in constructing table 1.

It may be pointed out that the frequency distribution thus obtained is a slightly altered form of binomial distribution which was described by Bernoulli early in the eighteenth century. If p is equal to the fractional or decimal part diseased, and q $(=1-p)$ the healthy, the expected frequency for various classes is obtained for groups of three by the terms obtained in expanding $(p+q)^3$ as follows.

$$
\begin{array}{lcccc}
(p+q)^3 = & p^3 & +\,3p^2q & +\,3pq^2 & +\,q^3 \\
 & & \text{DDH} & \text{DHH} & \\
 & \text{DDD} & \text{HDD} & \text{HHD} & \text{HHH} \\
 & & \text{DHD} & \text{HDH} &
\end{array}
$$

This as indicated above, has the disadvantage of throwing together classes, the central plants of which could be expected to differ in yield. For our purposes, then, the expansion may be written in the following obviously equivalent form to represent the expected frequency of the classes written below.

$$
\begin{array}{lcccccc}
(p+q)^3 = & p^3 & +\,2p^2q & +\,p^2q & +\,2pq^2 & +\,pq^2 & +\,q^3 \\
 & & \text{DDH} & & \text{DHH} & & \\
 & \text{DDD} & \text{HDD} & \text{DHD} & \text{HHD} & \text{HDH} & \text{HHH}
\end{array}
$$

The terms of this expansion may be used to estimate the expected frequencies of these different classes for any percentage of disease as those in table 1 or any intermediate percentage.

When the yields of each of these classes has been determined in a field test, the yields might be multiplied by the expected frequencies

to give an estimated yield for any percentage of disease. Thus if the yields of the classes are represented by the letters A. B. C. . . .F the estimated yield (Y) for any percentage of disease might be indicated by or computed from the equation—

$$Y = Ap^3 + 2Bp^2q + Cp^2q + 2Dpq^2 + Epq^2 + Fq^3$$

The expected frequencies of the different classes for certain percentages of disease have been computed and are given in table 1, for the convenience of those who may wish to try this method. An examination

TABLE 1.—*Estimated percentages of plants in a field situated like the central plants in the various classes for fields with different percentages of disease*

Percentage Disease in the Field	HHH	DHD	HHD DHH	DDD	HDH	HDD DDH
Any Percentage	$q^3/100$	$p^2q/100$	$2pq^2/100$	$p^3/100$	$pq^2/100$	$2p^2q/100$
0	100					
10	72.9	.9	16.2	0.1	8.1	1.8
20	51.2	3.2	25.6	.8	12.8	6.4
30	34.3	6.3	29.4	2.7	14.7	12.6
40	21.6	9.6	28.8	6.4	14.4	19.2
50	12.5	12.5	25.0	12.5	12.5	25.0
60	6.4	14.4	19.2	21.6	9.6	28.8
70	2.7	14.7	12.6	34.3	6.3	29.4
80	.8	12.8	6.4	51.2	3.2	25.6
90	.1	8.1	1.8	72.9	0.9	16.2
100				100.0		

p = Fractional or decimal part diseased.
q = 1-p = Fractional or decimal part healthy.

of the table indicates that an evaluation of the yielding ability of the central plants in these different classes, might best be made by working with material containing about 50 per cent disease, in order to get readily approximately equal numbers in each of the different classes. Thus any field with a full stand of plants might be utilized for this purpose if approximately 50 per cent of the disease, of the kind being studied, were present in random arrangement, simply by marking the diseased plants. Each plant except end plants or those adjacent to skips could be classified in one of the classes, harvested, and the yield determined. Because of the variations in individual hills, considerable

numbers would be required to obtain dependable averages but since nearly all hills in a planting may be utilized these are readily obtained.

A planting for such a purpose might be made by a randomized plan and this method might be preferable in the case of a disease not easily recognized in all stages.

This method seems particularly desirable in cases where the presence of diseased or missing plants may have an influence on the yield of adjacent plants but if such influence is absent this also would be determined. An accompanying paper by Tuthill and Decker shows that there is such an influence on the adjacent hills in the case of leaf roll of potatoes and no doubt other cases will be found.

In applying this system to estimate the losses due to missing plants, only three classes would have to be considered, as obviously the missing hills themselves would yield nothing.

In the case of either missing hills or diseased plants, this method seems to have the advantage that it provides a reasonable basis for estimating the loss due to any percentage of disease rather than the losses due only to the particular percentages used in trials.

It may be remarked that if a seemingly reasonable assumption be made, *i.e.*, if the influence of diseased or missing plants on both sides of another plant is twice as great as the influence of a diseased or missing plant on one side only, then the equation given above for expected yields could be simplified to the equation of a parabola of the form—

$$Y = ap^2 + bp + c$$

That this assumption is justified remains to be determined from experimental evidence. Converting the equation to a parabola would seem to be of little use when determinations of losses are made by the methods outlined above, but it might be useful, in case several points were established on a yield curve by other methods, to fit these to a parabola. In this way intermediate points might be estimated with greater accuracy than by assuming a straight line relation.

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LOSSES IN YIELD CAUSED BY LEAF ROLL OF POTATOES

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A method for the determination of losses in yield caused by diseased or missing plants of row crops is described by Blodgett in the preceding article. In this article the writers report the results of the application of this method to two varieties of potatoes, Chippewa and Cobbler, affected with leaf roll and grown on peat soil near Elba, New York.

Methods

In Mid-July a search was made for potato fields with nearly a perfect stand and showing approximately 50 per cent leaf roll plants distributed at random. Two fields were selected in which to operate. These were of the two varieties: Chippewa with about 35 per cent, and Cobbler with 23 per cent of the plants affected with leaf roll.

In the field of the Chippewa variety sufficient numbers of leaf roll plants were staked to have about 92 central plants in each class. A similar procedure was followed in the Cobbler field but, because of the low percentage of leaf plants and the limited area of peat of uniform depth, the number of plants in the six classes differed considerably, as indicated in table 1.

TABLE 1.—*Number of hills, average weight per hill, and yield in bushels per acre, of the central plants harvested in the six classes*

Variety	Classes	HHH	DHH HHD	DHD	HDH	DDH HDD	DDD
Chippewa	No. of hills	91	92	92	92	92	92
	Ave. yield in lbs.	2.059	2.196	2.408	1.221	1.257	1.222
	Yield bu. per acre	616.6	657.6	721.1	365.6	376.4	365.9
Cobbler	No. of hills	528	309	35	132	147	59
	Ave. yield in lbs.	1.537	1.698	1.8914	.6545	.7823	.722
	Yield bu. per acre	363.5	401.6	447.3	154.8	185.0	170.8

The potatoes were harvested by hand soon after the vines died and the yields of the central hills were recorded according to the scheme outlined in the preceding paper.

Results

The average yield in pounds per hill and in bushels per acre and the number of hills harvested in each class are presented in table 1. These averages, in the case of the Chippewa variety were obtained from 91 to 92 hills harvested in each class, but for the Cobbler variety the averages are based on the numbers varying from 35 in class DHD to 528 for the class HHH. Nevertheless, the results for both varieties show the same distinct trend in yields. There was a reduction caused by leaf roll, regardless of whether the plants adjacent to the central plant were healthy or diseased. They also show that healthy plants compensate, in part, for the losses in yield caused by leaf roll plants in the same field.

An examination of the yields by Fisher's analysis of variance (Tables 2 and 3) disclosed highly significant differences among the yields of the central plants between the different classes. The most significant difference was found between the yields of the healthy and diseased plants. There were also highly significant differences in yields between the central hills of the three healthy classes according to the condition of the adjacent plants in the case of both the Chippewa and Cobbler varieties. The results of the yields of the diseased plants were not subject to clear interpretation. In the case of the Chippewa variety there were no significant differences between the yields of the diseased

TABLE 2.—*Statistical analysis of Chippewa yields*
Fisher's analysis of variance

	D.F.	Sums of Squares	Mean Square	Ratio	
Total	550.	395.33			
Classes	5	140.31	28.06	60.0	xx
Error	545	255.02	.4679		
D vs. H	1	134.60	134.60	287.67	xx
Among H	2	5.64	2.82	6.03	xx
Among D	2	.08	.04		N
HHH *vs.* DHD	1	5.548	5.548	11.86	xx
HHH — 2HHD + DHD	1	.092	.092		N

xx Differences significant with odds 99:1.
n Differences not significant.

TABLE 3.—*Statistical analysis of Cobbler yields*
Fisher's analysis of variance

	D.F.	Sums of Squares	Mean Square	Ratio	
Total	1209	608.86			
Classes	5	200.52	40.10	118.2	xx
Error	1204	408.34	.34		
D vs. H	1	191.42	191.42	564.3	xx
Among H	2	7.97	3.98	11.75	xx
Among D	2	1.13	.57	1.67	N

xx Differences significant with odds 99:1.
n Differences not significant.

central plants in these three classes, indicating that the yield of the leaf roll plants was not influenced by the condition of the adjacent plants. With the Cobbler variety, however, there was considerable variation between two of the disease classes. Since this difference is between class HDD and class HDH, with the yield of the plants in class DDD falling intermediate between the above two classes, it appears unlikely that the difference can be accounted for by competition between adjacent plants.

The anticipated yields and losses due to varying percentages of leaf roll are presented in table 4. The actual yields for both the Cobbler and Chippewa varieties are given for zero and 100 per cent leaf roll infection. As outlined in the preceding article, when the average yields for the central plants in the six classes are known, the expected yields for any percentage of leaf roll can be calculated from the formula

$$Y = Aq^3 + (2Bpq^2 + Cp^2q + Dpq^2 + (2)Ep^2q + Fp^3$$

The reduction in yield caused by leaf roll was 53 per cent for the Cobbler variety and 40.1 per cent for the Chippewa variety.

With respect to these expected yields for different percentages of leaf roll, it is evident that an increase in the amount of leaf roll does not cause the same loss in yield throughout the whole range. Therefore, the first 20 per cent of leaf roll in the case of the Cobbler variety is credited with causing a yield reduction of 7.5 per cent, whereas an increase of 20 per cent of leaf roll above 70 per cent acounted for an additional 13.6 per cent loss in yield. This is a reflection of the fact that at these higher percentages of disease there are fewer healthy plants adjacent to leaf roll plants to offset in part for the yield losses caused by the latter.

TABLE 4.—*Effect of leaf roll on yield of Cobbler and Chippewa potatoes on peat soil*

Per Cent of Leaf Roll	Chippewa		Cobbler	
	Expected Yields Bu. per Acre	Per Cent Loss Due to Leaf Roll	Expected Yields Bu. per Acre	Per Cent Loss Due to Leaf Roll
0	616.6*	0.0	363.5*	0.0
10	599.3	2.8	350.1	3.7
20	580.9	5.8	336.3	7.5
30	561.3	9.0	321.6	11.5
40	540.1	12.4	305.9	15.8
50	517.2	16.1	288.7	20.6
60	492.1	20.2	269.8	25.8
70	464.7	24.6	248.9	31.5
80	434.7	29.5	225.6	37.9
90	401.9	34.8	199.7	45.1
100	365.9*	40.7	170.8*	53.0

*Actual yield.

Discussion and Conclusions

The data presented confirm the general opinion that leaf roll plants in a field do influence the yield of a potato crop. The healthy hills bordered by leaf roll plants on one or both sides will, in part, make up in yield for the losses caused by the diseased plants. Since the yield varies with the change in percentage of leaf roll plants present, the binomial distribution outlined by Blodgett in the preceding article may be used to estimate how frequently healthy plants will occur with leaf roll plants on one or both sides in a random distribution. Therefore, there is a basis for estimating the loss in yield for any percentage of disease by determining the yield of the central plants in the six classes given. Even though this method has been tried only with leaf roll of potatoes it would seem to be equally applicable to nearly all other potato diseases transmitted through the tuber, as well as to missing hills, and to any row crop in which competition occurs between adjacent plants.

RESULTS OF ATTEMPTED ERADICATION OF BACTERIAL RING ROT FROM POTATOES[1]

Dudley Peters Glick[2]

Colorado Agricultural Experiment Station, Fort Collins, Colo.

In June, 1939, Metzger and Glick (2) initiated an attempt to eradicate bacterial ring rot from small lots of certain varieties of potatoes that are standard for Colorado. This paper is a report of progress describing observations on the first year's increase from the 1939 experiments.

Methods and Results

The examination of stem smears made from vines in the experimental plot at the Mountain Substation of the Colorado Agricultural Experiment Station at Minturn, Colorado, was completed on the fifteenth of December 1939. The results of the examination were sent to the Mountain Substation where the tubers, which had been dug from tuber units and sacked separately in units, were in storage. Units, suspected of being infected, were discarded during January, 1940. On the 25th of March 1940, the tubers were transferred by truck to storage at the San Luis Valley Substation, north of Monte Vista, Colorado.

I. One sack of each of five strains of the Red McClure variety was returned to the San Luis Valley farm of the grower who supplied these strains originally. There they were planted on the first of June, 1940. Field inspections and stem smears made during the growing season failed to reveal ring rot infection in any of these lots.

II. On the 3d of June, 1940, all the remaining tubers were removed from storage and were transferred by truck to the Fort Lewis branch of the Experiment Station near Hesperus, in southwestern Colorado. With the exception of three lots all other tubers were designated as "double-smeared"; that is, during the 1939 season smears were made from the tuber at time of planting and from the stem of the vine at time of harvest. Strains R and S of the Bliss Triumph variety and the variety CS-110 were designated as "single-smeared", since only tuber smears of these lots were examined in the 1939 season.

At Fort Lewis the tubers were planted at once in an isolated field.

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[2]Pathology and Bacteriology Section.

According to seed size some were planted in tuber units whereas others were planted singly. The amounts of the varieties planted are shown in table 1. During cutting, the knives were treated with a 1:15 solution of Semesan Bel. All of the seed was treated with the same solution. A five-gallon container of the disinfectant was mounted on the assisted-feed planter so that the solution dripped continuously on the feed wheel during planting.

The field was rogued throughout the summer for infections other than ring rot, and on the 21st of September stem smears were made for ring rot identification. Each strain of the different varieties was examined in the following manner: smears were first made from all vines that appeared to be abnormal, regardless of the apparent cause of the abnormality. Additional smears were then made from apparently normal vines selected at random so that a total of 100 smears was taken from each variety.

The smears were fixed by heat and were stained by the Gram method recommended by Racicot, Savile, and Conners (3). They were then examined for the presence of bacteria resembling *Phytomonas sepedonica*. All varieties except Katahdin appeared to be free from ring rot infection. Of the 4,000 hills, nine were found to be infected in this variety.

On the 27th of September, following a microscopic examination of the smears, 85 tuber units of the Katahdin variety were dug by hand and stem smears were made from the vines in each hill. The tubers from each unit were sacked separately and then placed in storage at Fort Lewis. A subsequent examination of the smears indicated that the units were not infected.

From the 15th to the 19th of October the remaining varieties were harvested with a digger and were stored at Fort Lewis. Small increments of some of these lots will be offered to selected foundation growers for increase during 1941; the major portion will be planted for increase at Fort Lewis.

Discussion

The apparent failure of the microscopic method to produce a lot of tubers free from ring rot infection in the case of the Katahdin variety may arise from one of several factors: healthy tubers may have become infected by contact during handling and storage before the units known to be infected were discarded; the incidence of infection in this variety appears to be great in Colorado and field symptoms are not always easily

TABLE 1.—*Data of attempted eradication of ring rot from potatoes*

Variety	Site of Planting	No. of Hills Planted	No. Infected Hills Found
BLISS TRIUMPH			
Strain M	Fort Lewis	1,200	—
Strain R[1]	" "	1,600	—
Strain S[1]	" "	800	—
CHIPPEWA	" "	600	—
CS-110[1]	" "	2,000	—
IRISH COBBLER			
Strain J	" "	600	—
Strain M	" "	2,000	—
KATAHDIN	" "	4,000	9
RED McCLURE			—
Strain SS	" "	2,000	—
Strain S-36	" "	1,000	—
Strain S-39	" "	600	—
Strain S-47	" "	800	—
Strain S-84	" "	2,800	—
Strain SS	San Luis Valley	800	—
Strain S-36	" " "	800	—
Strain S-39	" " "	800	—
Strain S-47	" " "	800	—
Strain S-84	" " "	800	—
RURAL NEW YORKER	Fort Lewis	1,000	—
RUSSET BURBANK	" "	1,000	—
RUSSET RURAL	" "	800	—
WHITE ROSE	" "	600	—
Total		27,400	9

[1]Strains R and S of the Bliss Triumph variety and the CS-110 variety were single-smeared. All others were double-smeared.

recognized; although symptoms are frequently manifest, it may be that the Katahdin variety serves as a carrier of the ring rot organism under conditions of altitude, climate or culture unknown to us.

In view of the apparent success with other varieties the failure to eliminate ring rot from one variety does not seem to justify condemnation of the microscopic method. Whether a further application of the method will succeed in producing a ring-rot-free lot of the Katahdin variety will be seen by the results of the 1941 planting.

The use of ultraviolet light as introduced by Iverson and Kelly (1) does not appear to the workers at the Colorado Agricultural Experiment Station to be as satisfactory as the microscopic method for the elimination of ring rot. In our hands, although offering promise as a routine device to be recommended because of its simplicity and speed of operation, the ultraviolet light method has not yielded results that are comparable in accuracy to the microscopic method for research purposes. Where a critical analysis of infection is desired, it is our belief that a demonstration of the etiologic agent of infection is superior to reliance on symptoms. This statement, however, is not to be construed as a condemnation of the ultraviolet light method as an aid to growers and inspectors who must subject large numbers of tubers to rapid examination without the necessity of obtaining complete eradication of an infection. Indeed, information on the use of ultraviolet light is being offered to growers in Colorado in order that the incidence of infection may be reduced in seed stocks now in use.

Summary

Results of the first year's increase of selected lots of seed potatoes, upon which the microscopic method was used in an attempt to eradicate bacterial ring rot, are presented. The method was apparently successful in all lots except one of the Katahdin variety. The use of the method has been continued in an attempt to produce a ring-rot-free lot of this variety.

Acknowledgment

Invaluable assistance in handling, planting, cultivating, roguing, and harvesting of the experimental plot is gratefully acknowledged. Those who cooperated were Mr. Ralph Manuel and Dr. John G. McLean of the Experiment Station and Mr. W. Frank McGee of the Extension Service, of Fort Collins, and Mr. Dwight Koonce of the Fort Lewis branch of the Experiment Station.

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A TEST OF THE POSSIBILITIES OF PHOTOPERIODIC INDUCTION OF BLOOMING IN TRIUMPH POTATOES AND THE MORPHOLOGICAL CONSEQUENCES

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In earlier work (2, 3, 4) we have reported that flowers did not develop on potato plants during the short winter days. We also demonstrated that when potato plants were subjected to short winter days for a month or more it was not possible to induce them to resume vegetative growth or to produce flowers by subjecting them to long photoperiods. We were very successful in producing potato flowers and berries in the spring of 1937 and of 1938 with 16-hour photoperiods. The publication in the spring of 1938 by Borthwick and Parker (1) of their discovery that soybeans could be induced to bloom by two short photoperiods, suggested to us that possibly the use of a long photoperiod during the early life of the potato plant might suffice to induce it to bloom. In a practical breeding program the economy of such a method is obvious. In the winter of 1938-'39 an attempt was made to determine the possibilities along this line.

Tubers of Triumph Strain 12 (a very early clonal line) were cut and planted in sand the 31st of December. The sprouting seed pieces were transplanted to gravel in 10″ pots on the 1st of February, 1939. Two seed pieces were planted in each pot. The nutrient solution used was that of Withrow (5). The plan was to secure short photoperiods by covering plants with light weight cardboard cylinders which were painted white on the outside to prevent heating during the day. Plants of one treatment were randomized as to position in 5 series. Because of the uneven emergence a separate schedule was arranged for every pot or plant so that the desired photoperiod occurred for the proper interval of time following emergence. The length of the short photoperiod was eight hours. The greenhouse temperature averaged about 60° at night and 70°-75° F. during the day. The light used for the supplemental part of the photoperiod amounted to 20 to 30 foot candles at the tops of the plants. Our project was terminated on the 4th of May when plants were maturing. At that time the weight of the tops and the number of tubers were determined for each plant.

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[1]Professor of Horticulture.

[2]Published as Journal Series No. 276 with the approval of the Director of the Nebraska Agricultural Experiment Station. Dec. 20, 1940.

TABLE 1.—*Essential data concerning vegetative aspects and tuber production of Triumph strain 12, plants subjected to 8-hour days for weeks specified and to 16-hour days for balance of life*

Set No.	Weeks of Short Days	Mean Emergence Date in February	Mean Plant Height Cm.	Number of Nodes		Plant Maturity May 4th*	Tubers		
				Above Ground	Total		Mean No. per Plant	Mean Wt. per Plant Gms**	Weighing over 5 Gms.
1	1, 2, 3, 4, 5	13	27.1	14.2	25.5	4.6	9.7	130.0	123.5
2	1, 2, 3, 4	13	26.1	13.3	24.4	3.6	10.8	131.8	123.7
3	1, 2, 3	10	32.2	14.6	26.0	4.0	15.6	180.7	162.8
4	1, 2	10	42.4	14.7	25.6	4.3	12.2	215.8	206.3
5	1	9	50.7	14.8	25.7	4.1	11.4	272.3	241.9
6	- - - - -	10	49.0	14.8	25.8	2.4	17.3	246.1	223.0
7	2nd	10	36.9	15.0	25.8	2.6	14.6	175.3	154.0
8	3rd	11	37.2	14.9	26.6	2.7	16.4	219.0	205.0
9	4th	10	44.9	15.6	26.8	5.6	13.1	231.0	210.6
10	5th	11	56.7	15.6	26.5	4.8	16.1	231.9	221.4
11	4, 5	12	46.8	14.8	25.9	4.4	10.6	237.8	190.5
12	3, 4, 5	9	33.0	13.6	25.6	6.2	13.3	177.0	160.0
13	2, 3, 4, 5	9	24.8	13.5	25.4	6.6	12.1	157.8	142.5
14	1, 2, 3, 4, 5	12	27.2	13.9	25.5	5.4	11.1	138.8	131.1
15	1, - 3, 4, 5	9	30.5	14.6	26.0	3.8	12.8	190.1	180.8
16	1, 2, - 4, 5	10	34.7	15.1	25.9	4.2	9.7	172.0	163.5
17	1, 2, 3, - 5	9	35.2	14.5	26.1	3.2	10.1	177.7	168.9
18	1, - - 4, 5	13	38.9	15.5	26.6	2.7	14.5	194.7	166.9
19	1, 2, - - 5	13	35.8	13.4	25.5	5.0	9.9	198.1	193.4
20	- 2, 3, - -	9	30.8	14.2	25.8	3.2	13.8	209.4	202.1
21	- - 3, 4, -	12	38.2	15.2	25.6	4.8	10.5	195.8	187.9
22	- - - - -	12	52.0	15.6	26.4	3.8	13.8	227.8	200.2
23	- 2, - 4, -	13	33.9	14.3	25.5	2.0	10.1	181.5	163.1
24	1 - 3, - 5	12	33.2	13.1	25.1	3.2	10.2	174.4	170.6

*Maturity estimated on basis of 1.0 least mature, 10 entirely mature.

**Difference for significance—65.02, Differences significant at 1 per cent level.

Results

Most flower primordia dropped off before they reached the overlapping calyx bud stage and all these dropped before developing into flowers except in the set that was grown continually in a 16-hour day. In that set a total of 10 flowers opened on three clusters but none of them produced any berries.

The plants were tallest and had the greatest number and weight of tubers when grown in 16-hour days continually or with only one week of 8-hour days (Table 1). As the number of weeks during which 8-hour days were used decreased there was a decrease in plant height and tuber production and a trend in the direction of fewer tubers per plant (Table 2). As 8-hour days were used for a decreasing number of weeks toward the close of the 5-week period there was a steady increase in plant height and tuber weight and a pronounced trend toward an increasing number of tubers (lots 1 to 6). With a given number of weeks of 8-hour days at the end of the 5-week period plants were usually taller than with short days the same number of weeks following emergence. When treatments differed as to duration of short photoperiods by 3 or more weeks the tuber weight differences were

Table 2.—*Effect of 8- and 16-hour days for various numbers of weeks upon plant height and number and weight of tubers*

Lot No.	Length of Day During Each of First 5 Weeks (L = 16 hrs. S = 8 hrs.)					Mean Height of Plants Cms.	Tubers per Plant: Mean Number	Tubers per Plant: Mean Weight* Gms.
6	L	L	L	L	L	49.0	17.3	246
5	S	L	L	L	L	50.7	11.4	272
4	S	S	L	L	L	42.4	12.2	216
3	S	S	S	L	L	32.2	15.6	181
2	S	S	S	S	L	26.1	10.8	132
1	S	S	S	S	S	27.1	9.7	130
14	S	S	S	S	S	27.2	11.1	139
13	L	S	S	S	S	24.8	12.1	158
12	L	L	S	S	S	33.0	13.3	177
11	L	L	L	S	S	46.8	10.6	238
10	L	L	L	L	S	56.7	16.1	232
22	L	L	L	L	L	52.0	13.8	228

*Difference for significance = 65.02. Difference highly significant at 1 per cent level.

TABLE 3.—*Effect of introducing a week of 8-hour days among the first 5 weeks of 16-hour days upon plant height and number and weight of tubers*

Lot No.	Length of Day During Each of First 5 Weeks (L = 16 hrs. S = 8 hrs.)	Mean Height of Plants Cms.	Tubers per Plant: Mean Number	Tubers per Plant: Mean Weight Gms.*
6	L L L L L	49.0	17.3	246
22	L L L L L	52.0	13.8	228
5	S L L L L	50.7	11.4	272
7	L S L L L	36.9	14.6	175
8	L L S L L	37.2	16.4	219
9	L L L S L	44.9	13.1	231
10	L L L L S	56.7	16.1	232

*Significant differences—65.02; Differences highly significant at 1 per cent level.

highly significant. For smaller differences in treatments trends were constant but differences were statistically less significant.

A single week of 8-hour days resulted in a reduction in plant height and tuber weight if the short days occurred during the 2nd or 3rd week (lots 1 and 8). Single weeks of short days occurring at any other time did not exert a distinctive influence upon plant height or tuber production (Table 3).

When short days occurred for adjacent two-week periods they appeared to exert an inhibiting effect upon plant size and tuber production if they occurred in the second or third or perhaps the third and fourth weeks (lots 20, 21). Short days during the first and second or fourth and fifth weeks brought about a smaller and less significant inhibitory effect. When a short photoperiod was used in the second and fourth weeks (lot 23) plant size, tuber number, and tuber weight were all low (Table 4).

Three weeks of short days caused a reduction in size of plant and weight of tubers regardless of when the weeks occurred. Greatest reduction seemed to be associated with short days if these occurred in three alternating weeks. When they occurred consecutively either at the beginning or end of the 5-week period, they caused greater reductions than correspondingly located two-week periods.

Four weeks of short days caused a greater reduction in plant size and tuber production than did three weeks. Short days for four consecutive weeks after emergence resulted in least tuber production.

TABLE 4.—*Effect of short days when used for various 2-, 3-, or 4-week periods throughout the first five weeks upon plant size, and number and weight of tubers*

Lot No.	Length of Day During Each of First 5 Weeks (L = 16 hrs. S = 8 hrs.)					Mean Height of Plants Cms.	Tubers per Plant Mean Number	Tubers per Plant Mean Weight Gms.*
			Two-week intervals					
6	L	L	L	L	L	49.0	17.3	246
22	L	L	L	L	L	52.0	13.8	228
4	S	S	L	L	L	42.4	12.2	216
20	L	S	S	L	L	30.8	13.8	209
21	L	L	S	S	L	38.2	10.5	196
11	L	L	L	S	S	46.8	10.6	238
23	L	S	L	S	L	33.9	10.1	182
			Three-week intervals					
3	S	S	S	L	L	32.2	15.6	181
12	L	L	S	S	S	33.0	13.3	177
19	S	S	L	L	S	35.8	9.9	198
18	S	L	L	S	S	38.9	14.5	195
24	S	L	S	L	S	33.2	10.2	174
			Four-week intervals					
2	S	S	S	S	L	26.1	10.8	132
13	L	S	S	S	S	24.8	12.1	177
15	S	L	S	S	S	30.5	12.8	190
16	S	S	L	S	S	34.7	9.7	172
17	S	S	S	L	S	35.2	10.1	178

*Significant difference = 65.02: Difference highly significant at 1 per cent level.

GENERAL CONCLUSION

As the number of short-day weeks increased vegetative growth was inhibited and tuber weight and number were decreased.

A given number of weeks of short days in the beginning of the five week period following emergence caused a slightly greater reduction in vine size than if they occurred at the end of the 5-week period.

Short days for single weeks during the second and third weeks appeared to be most important in inhibiting vine size and causing low yields.

A 16 hour photoperiod with supplemental light of 20-30 foot candle intensity was not sufficient to induce blooming in an early strain of Triumph potatoes. As vegetative growth was inhibited and bud primordia dropped . . . as a result of short days occurring anytime during the first five weeks . . . it appears that in order to secure flowers and

berries with the Triumph variety a long bright photoperiod is needed for more than an induction period.

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SECTIONAL NOTES

ALABAMA

This week marked the first sizeable shipments of potatoes from the South Alabama section. The weather has been ideal throughout the season. The crop was planted under ideal conditions, and rains have occurred at sufficiently frequent intervals to give good steady growth without an excess at any one time.

The peak is expected about the third week of May. There has been no change in the early estimate of 8,000 to 10,000 cars from Baldwin County.

Shipments of White Rose are expected to reach 2,000 cars this year. The shipment of this variety will begin about ten days after the Triumphs have started.

This year we have better, larger, and more improved machinery than ever before, which should assure good grading, washing, and handling of the anticipated large crop.

It is believed that 400 cars per day can and will be handled at the peak of the season. (May 9).—L. M. Ware.

FLORIDA

The potato acreage in the Homestead section this past season was slightly less than 6,000 acres. With the exception of approximately 100 acres of Sebago, this acreage was planted to the Bliss

Triumph variety. Total yields were about normal, averaging between 175 to 200 bushels per acre. The average yield of marketable potatoes, however, probably did not exceed 135 bushels per acre.

Several adverse factors were responsible for the unusually high percentage of culls. Heavy rains during the growing season caused a high percentage of growth cracks and these rains are believed to be responsible for the dull color and poor finish on much of the stock produced. Late blight was epidemic and caused a high percentage of tuber rot which to this loss in some fields amounted to 35 per cent of the stock. In addition, from a trace to more than 50 per cent of the tubers in the earliest plantings were affected by a condition known as "healed holes." The latter is believed to be caused by larvae of Diabrotica beetles, particularly by the 12-spotted and the banded species. Wireworm damage was also quite severe on some farms.

The demand for early potatoes was low and the prices obtained were somewhat below normal. At present, the prospects for next season in the Homestead area show a greatly reduced acreage of potatoes. (May 12).—GEO. D. RUEHLE.

LOUISIANA

The early commercial potato crop is now moving to market. It is anticipated that our peak shipment will occur during the week of the 19th of May. Our yields are good but prices are disappointingly low. Northern certified seed has shown up somewhat better than in the last two years. However, some of the seed is marginal (May 14).—J. G. RICHARD.

NEW JERSEY

The potato crop in New Jersey was planted in record time. Many farmers planted their entire acreage during the three-week period from the 7th to the 26th of April. By the first of May all the potatoes were planted. During this period the temperatures were abnormally high and only one rainfall was recorded. This rainfall which amounted to .6 inches, occurred on the 23d of April.

The acreage is approximately the same as that of last year. Our plantings show an increase of the Katahdin and Chippewa varieties, with a corresponding decrease in Cobblers. Small acreages of Houma, Sebago, and White Rose have also been planted. This indicates an attempt on the part of our growers to obtain better varieties.

A large percentage of the seed used was certified stock and practically no seed piece decay has been noted, with the exception of a few cases where the seed was frosted when received.

Bacterial Ring Rot was found in two non-certified sources but the planting of this seed are very small. Our local late crop seed showed a considerable amount of late blight, and if the growing season should prove to be a wet one we may expect trouble from blight.

At the present time the potato plants are about one or two inches above ground and, in general, the stands are good. The recent showers we have experienced will be a great benefit to our crop, and all indications point to good yields. (May 12).—J. C. CAMPBELL.

NEW YORK

Weather conditions during April were very abnormal. Spring came early. Not only was the rainfall slightly subnormal but the mean temperature was several degrees above normal making conditions favorable for early planting. The Long Island plantings were delayed because of the cold weather during the latter part of March and the early part of April. Finally under favorable conditions during the middle and latter part of April the growers began their planting operations. Conditions upstate have been ideal so far in May and some of our biggest growers even on upland soil, had more than one-half their acreage planted by the 10th of May. We believe this early planting favors high yields. However, the quality of seed is probably below average not only because of the low temperatures, but also because of the blight situation last fall.

Announcement has been made that the twelfth annual potato field day of the Empire State Potato Club will be held on Thursday, the 14th of August. This year the big event is scheduled at the farm of Hugh G. Humphreys and Son, New Hartford, Oneida County, N. Y. Mr. Humphreys is one of New York's Master Farmers and a premier Potato Grower. Last year he harvested an average yield of 384 bushels from 25 acres of potatoes. In addition to the exhibits and demonstrations of modern potato machinery, there will be a special demonstration of digging potatoes planted on contour. (May 12).—E. V. HARDENBURG.

OREGON

The shipping season for our 1940 crop is just about over. So far we have shipped 9,500 cars of potatoes and diverted over 500 more under the livestock feed diversion program.

We have a total of 300 to 400 cars left.

Planting is under way,—about 10 days earlier than usual. Our acreage should be slightly smaller than last year. There is a demand for good seed. We are looking forward to approximately the same number of acres entered for certification. (May 13).—C. A. HENDERSON.

NORTH CAROLINA

The early potato crop in North Carolina looks very good at the present time. Climatic conditions have been very favorable. The stand is almost perfect where good seed was used except on low fields where the plants were drowned out. If the weather is not too dry during the rest of May, I would say that our crop prospects will be very good. The acreage is about the same as last year. Marketing conditions do not promise to be any better except for the fact that we have several large defense projects in the area, which will require a certain amount of the crop. (May 12).—ROBERT SCHMIDT.

SOUTH CAROLINA

The South Carolina potato crop is in good condition, although some fields are beginning to suffer from lack of water. A rain at this time would be very welcome and would probably result in greatly increased yields, especially in some sections along the coast. Present indications point to the fact that yields may be lower than usual because of the dry weather and because germination was retarded in March as a result of the prolonged cold period at that time.

There seems to be relatively little disease in most commercial fields. Mosaic and leaf roll, as usual, are in evidence but late blight has not appeared and there has been practically no early blight, scab, or rhizoctonia. Unless something unforeseen happens, growers in this state should dig a good, clean crop of high quality potatoes. Harvesting is expected to begin about the 15th of May and should be at its peak by the week after.

It may be interesting to growers in other sections to learn that practically every farm in the coastal section of this state has been

limed for potatoes, a practice that was once considered dangerous and unnecessary. Seven years ago many of the farms in this area were suffering from a deficiency of magnesium and from highly acid conditions. The pH of many soils where potatoes were being grown ran as low as 4.5, or even lower. Since that time every farm has been tested for soil reaction and potato fields in most cases have received enough dolomitic limestone or basic slag to bring the soil reaction up to pH 5.5 which is about optimum for potatoes. This has helped to eliminate magnesium deficiencies and has resulted in increased yields of better quality potatoes. Many growers apply a ton of 5-10-5 ferilizer per acre, and if tests show that it is needed they include magnesium and manganese in this mixture. Much of the fertilizer is now applied in bands at the sides of the seed pieces instead of in the row. (May 10).—J. MITCHELL JENKINS JR.

SOUTH DAKOTA

Potato planting is under way in South Dakota with ideal moisture conditions. Approximately a 10 to 15 per cent increase in the certified potato acreage is expected. Last season more than 1800 acres were entered for certification and this year the acreage will run between 2100 to 2200 acres. The largest acreage consists of Bliss Triumph, with Cobblers next and Early Ohios third. There will be a small acreage of Chippewas, and some Katahdins will also be planted.

This year most of the growers are using the acid mercury seed treatment and a few are using hot formaldehyde.

The prices received by growers for the 1941 crop were low but most of the stock has been sold at this time. Some growers are increasing their acreage because of the low prices offered for their certified seed stock.

Two auto loads of officials and potato growers from South Dakota attended the Louisiana and Alabama potato tours in April. South Dakota seed was performing well in those states.

New foundation stock of Bliss Triumphs and Cobblers has been shipped to us from western North Dakota. South Dakota growers had the advantage of the Federal Shipping Point inspection last season and this service was used on all shipments of certified seed (May 12).—JOHN NOONAN.

Potato Tours

The Nineteenth Annual Potato Field Day will be held here at the Eastern Shore Branch of the Virginia Truck Experiment Station, one mile south of Onley, Virginia, on Thursday, June 12, 1941.

Lunch will be served on the lawn at the Experiment Station at 12:00 o'clock, and the program will begin immediately after lunch.

The potato seed source demonstration should be of particular interest in that all the samples used this year were taken, by the County Agents of Accomack and Northampton Counties, directly from carlot shipments to this area. It is a tuber unit demonstration and should show some comprehensive results.

The Worcester County potato growers will also hold their Annual Potato Field Day on Thursday, June 12. This meeting will be held at 8:30 A. M., on the W. T. Pilchard Experimental Farm, one mile south of Pocomoke, Maryland, on Route 13.

The Annual Seed Potato Conference will be held on the Spencer Perrine farm, Cranbury, New Jersey, on June 24 and June 25.

Those who arrive by train will be met at the Roger Smith Hotel at 1 P. M., and those arriving by car will find the Spencer Perrine farm on Route 25.

The Annual Summer Meeting of the New Jersey State Potato Association will be held Thursday afternoon, June 25 in Monmouth County. The time and place of the meeting have not yet been decided.

The Long Island potato tour will be held June 26 and 27. Complete detailed information concerning the tour may be obtained by corresponding with Mr. H. H. Campbell, Minetola, New York, or W. S. Been, Riverhead, New York.

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THE INFLUENCE OF FERTILIZERS ON POTATO TUBER SHAPE*

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The initiation, in 1930, of fertilizer experiments with early-crop potatoes at the Lakin Experiment Farm of the West Virginia Agricultural Experiment Station afforded an opportunity to study, under field conditions, the effects of varying amounts of nitrogen, phosphoric acid, and potash on tuber shape. This seemed particularly opportune for two reasons: first, the Cobbler variety was to be grown, which because of its round shape and rapid tuber development would seem to lend itself readily to this sort of study; second, all of the crops were to be grown on the same area, the soil of which was a relatively uniform Wheeling fine sandy loam of good tilth—one roughly termed a "fast soil," on which ready response to even small differences in fertilizer composition might be expected.

The crop was grown in a three-year rotation consisting of potatoes, wheat and clover; hence data were available only every third year. Ten tons of manure per acre and the fertilizer mixtures were applied only for the potato crop. The fertilizer mixtures, composed of ammonium sulfate, superphosphate, and muriate of potash, were applied at the rate of 1000 pounds per acre in the row at planting time. All treatments were in triplicate. At harvest 200-tuber samples of No. 1

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tubers weighing no less than 3 ounces were taken from the mixed yields of the plots of each treatment and measured for length and width with a slide caliper. Care was taken that badly off-type or "knobby" tubers were not included in the samples. The treatment and formula used were as follows:

Check	5-12-7
No-N	0-12-7
Low-N	2.5-12-7
High-N	10-12-7
Low-P	5- 6-7
High-P	5-24-7
Low-K	5-12-3.5
High-K	5-12-14

In the analysis of the data, mean values of the measurements of the tuber length and width for each sample have been calculated and the corresponding values for each treatment compared with those of every other treatment. However, for brevity, only those comparisons which seem to lend weight to evident trends are included in the tables which follow. A difference between corresponding values is considered significant if it is three or more times its probable error.

The comparsions of the mean values of the measurements of the different tuber samples in 1933, given in table 1, fail to give significant differences in any case. Despite this fact there seems to be a general tendency, in the comparison of the mean measurements of the tubers from the check treatment with those from the plots which were treated with varying amounts of nitrogen, for increased amounts of nitrogen to depress both tuber length and width—more particularly the length. A comparison of the tubers from the check treatment with those from the high-P and low-P treatments, together with a comparison of the tubers of these last-mentioned treatments, indicates that the mixtures having the larger amounts of phosphoric acid increased both tuber length and width, but more particularly length. Similar comparisons made with respect to potash suggest that the tuber width was increased a little. The tuber length and width ratios substantiate the direct comparisons made above. In general, this study seems to indicate that nitrogen reduced tuber length but apparently had little influence on width. Phosphorus tended to increase both dimensions—especially tuber length. Potash, on the other hand, seems to have increased tuber width to a slight degree.

TABLE I—*Comparison of mean measurements in centimeters of tuber samples from potato fertilizer experiments at the Lakin Experiment Farm in* 1933

Treatment and Measurement		L/W*	Mean Values	Differences with D/PE Values between Mean Measurements of Compared Tuber Samples									
				Check		Low-N		High-N		High-P		High-K	
				Difference	D/PE	Difference	D/PE	Difference	D/PE	Difference	D/PE	Difference	D/PE
Check	L W	1.047	6.57 ± 0.19 6.28 ± 0.16										
No-N	L W	1.036	6.73 ± 0.18 6.49 ± 0.14	—0.16 ± 0.27 —0.21 ± 0.21	0.59 1.00	—0.03 ± 0.26 —0.04 ± 0.20	0.12 0.20	—0.37 ± 0.25 —0.22 ± 0.20	1.48 1.10				
Low-N	L W	1.040	6.70 ± 0.18 6.45 ± 0.14	—0.13 ± 0.26 —0.17 ± 0.22	0.50 0.77			—0.34 ± 0.24 —0.18 ± 0.20	1.42 0.90				
High-N	L W	1.015	6.36 ± 0.17 6.27 ± 0.15	+0.21 ± 0.26 —0.01 ± 0.21	0.81 0.05					+0.33 ± 0.26 +0.16 ± 0.26	1.27 0.62	+0.17 ± 0.23 +0.21 ± 0.20	0.74 1.00
Low-P	L W	1.014	6.35 ± 0.16 6.26 ± 0.14	+0.22 ± 0.25 +0.02 ± 0.21	0.88 0.10					+0.34 ± 0.26 +0.17 ± 0.26	1.31 0.65		
High-P	L W	1.040	6.69 ± 0.20 6.43 ± 0.21	—0.12 ± 0.27 —0.15 ± 0.27	0.44 0.56							—0.16 ± 0.25 +0.04 ± 0.26	0.64 0.17
Low-K	L W	1.017	6.43 ± 0.19 6.32 ± 0.12	—0.14 ± 0.26 —0.04 ± 0.20	0.54 0.20							+0.10 ± 0.24 +0.15 ± 0.24	0.42 0.63
High-K	L W	1.009	6.53 ± 0.16 6.47 ± 0.14	—0.04 ± 0.24 —0.19 ± 0.21	0.17 0.90								

*L and W designate tuber length and width.

Comparisons of the 1936 measurements similar to those made from the 1933 measurements are given in table 2. The tubers from the plots having had the high-N treatment were significantly longer than those from the plots which had the check treatment. This was true with respect to the high-P plots. The tubers from the high-K plots were also longer but the difference lacked significance. The tubers from these same treatments also tended to be wider, only that difference involving the high-P treatment being significant. The differences between the tubers which had the check treatment and those from the treatments which had the lower amounts of the different elements were small and inconsistent. A comparison of the tubers from the plots in which the amount of nitrogen was varied shows the tubers which had the high-N treatment to have been definitely longer and somewhat wider; besides, the tubers which had the high-N treatment differed little in either measurement from those which had the high-P and the high-K treatments. Those from the plots with the high-P treatment were longer and wider than those from the low-P treatment—the larger difference being in length. Although the same holds true for the tubers from the high-K plots, the differences were less. A comparison of the tubers from the plots which had the high-P treatments with those from the plots which had the high-K treatment shows the latter to have been shorter and possibly narrower. These data suggest that nitrogen and phosphorus in the order named directly affected tuber length, whereas potash, if it influenced tuber shape at all, broadened them. The tuber length and width ratios verify this.

The comparisons of the tuber measurements made in 1939 are given in table 3. Comparisons of the tubers from the check plots with those from the plots which had the larger amounts of the three elements show that, although the high-N treatment increased both tuber length and width, length was affected most. Similarly the high-P treatment increased both tuber length and width but it affected width more than length, as did the high-K treatment. The tuber comparisons involving the different amounts of nitrogen show this element to have increased both dimensions, but to a greater degree it increased length. A similar consideration of the comparisons of the measurements of tubers from the plots which had the high-P and the low-P treatments shows this element to have increased tuber length definitely and to some extent to have decreased width. Potash increased both dimensions significantly to approximately the same degree. The tubers from the high-N plots were significantly longer and somewhat wider than those from the high-P plots. In the case of the high-K plots as compared

TABLE 2—*Comparison of mean measurements in centimeters of tuber samples from potato fertilizer experiments. Lakin Experiment Farm in 1936*

Treatment and Measurement		L/W*	Mean Values	Check Difference	Check D/PE	Low-N Difference	Low-N D/PE	High-N Difference	High-N D/PE	High-P Difference	High-P D/PE	High-K Difference	High-K D/PE
Check	L	1.221	6.68 ± 0.07										
	W		5.47 ± 0.06										
No-N	L	1.234	6.81 ± 0.08	−0.13 ± 0.10	1.30	−0.15 ± 0.10	1.50	+0.21 ± 0.11	1.91				
	W		5.52 ± 0.05	−0.05 ± 0.07	0.71	−0.10 ± 0.07	1.43	+0.09 ± 0.07	1.29				
Low-N	L	1.229	6.66 ± 0.07	+0.02 ± 0.10	0.20			+0.36 ± 0.10	3.60				
	W		5.42 ± 0.05	+0.05 ± 0.07	0.71			+0.19 ± 0.07	2.71				
High-N	L	1.253	7.03 ± 0.07	−0.35 ± 0.10	3.50					+0.01 ± 0.11	0.91	−0.11 ± 0.11	1.00
	W		5.61 ± 0.05	−0.14 ± 0.08	1.75					+0.03 ± 0.07	0.43	+0.01 ± 0.07	0.14
Low-P	L	1.224	6.72 ± 0.07	−0.04 ± 0.10	0.40					+0.32 ± 0.11	2.91		
	W		5.49 ± 0.05	−0.02 ± 0.07	0.29					+0.15 ± 0.07	2.14		
High-P	L	1.246	7.03 ± 0.08	−0.35 ± 0.11	3.18							−0.12 ± 0.11	1.09
	W		5.64 ± 0.05	−0.17 ± 0.07	2.43							−0.03 ± 0.07	0.43
Low-K	L	1.227	6.81 ± 0.07	−0.13 ± 0.10	1.30							+0.11 ± 0.11	1.00
	W		5.55 ± 0.05	−0.08 ± 0.07	1.14							+0.07 ± 0.07	1.00
High-K	L	1.231	6.92 ± 0.08	−0.24 ± 0.10	2.40								
	W		5.62 ± 0.05	−0.15 ± 0.08	1.88								

*L and W designate tuber length and width.

with those from the high-N plots, the tubers were significantly shorter but were slightly wider. The tubers from the high-P plots when compared with those from the high-K plots showed the latter to be definitely wider and somewhat longer. These comparisons together with the tuber length and width ratios show that nitrogen and phosphoric acid in the order named had greatest influence on tuber length. Potash increased tuber width.

In the consideration of these results as a whole it is appreciated that the differences obtained from the comparisons of the tuber measurements taken in 1933 and in 1936, for the most part, are small and of little statistical significance. As shown in table 4, both of these seasons, though different in detail, were decidedly unfavorable to potato production. This, together with the facts that only a moderate dosage of the fertilizer mixtures was applied and that these mixtures were composed of ingredients of only ordinary availability is probably responsible for the small differences in growth response obtained. They, despite their smallness, appear, with few exceptions, to signify definite trends and are here considered of value.

The measurements taken in 1936 and 1939 show the high-N treatment to have definitely caused tuber elongation with a lesser effect on tuber width, which is in agreement with the results of Neumann (1), Martin, *et al* (2), Metzger (3), and others. However, this treatment resulted in a reduction in tuber length in 1933, which can probably be attributed to the unfavorable growth conditions which prevailed. Late planting resulted from an extremely wet spring which was followed in mid-June by drought conditions. These data strongly suggest that growth was inhibited by the nitrogen carrier of the fertilizer mixtures under the prevailing drought conditions, since this element retarded elongation whereas those elements which are most readily "fixed" appear to have affected tuber shape least.

The high-P treatment appears to have been general in its effect, influencing length most, under the adverse growing conditions which prevailed in 1933 and 1936, whereas the tuber width was generally affected most under the favorable seasonal conditions of 1939. These apparent inconsistencies may account for the different results reported by other investigators. Neumann found, under conditions of plentiful moisture, that phosphoric acid had greatest influence on tuber width. Martin, *et al,* and Harrington (4), obtained little or, at most, an intermediate effect, whereas Metzger got elongation with the use of a high phosphoric acid fertilizer. The same has been more recently reported by Prince *et al.* (5)

TABLE 3—*Comparison of mean measurements in centimeters of tuber samples from potato fertiliser experiments. Lakin Experiment Farm in 1939*

Treatment and Measurement		L/W*	Mean Values	Differences with D/PE Values between Mean Measurements of Compared Tuber Samples									
				Check		Low-N		High-N		High-P		High-K	
				Difference	D/PE	Difference	D/PE	Difference	D/PE	Difference	D/PE	Difference	D/PE
Check	L	1.159	6.91 ± 0.05										
	W		5.96 ± 0.03										
No-N	L	1.130	6.79 ± 0.05	—0.12 ± 0.06	2.00	+0.04 ± 0.06	0.67	+0.57 ± 0.06	9.50				
	W		6.01 ± 0.03	+0.05 ± 0.05	1.00	+0.10 ± 0.05	2.00	+0.24 ± 0.05	4.80				
Low-N	L	1.118	6.83 ± 0.04	—0.08 ± 0.06	1.33			+0.53 ± 0.06	8.83				
	W		6.11 ± 0.03	+0.15 ± 0.05	3.00			+0.14 ± 0.05	2.80				
Hi-N	L	1.178	7.36 ± 0.05	+0.45 ± 0.06	7.50					—0.31 ± 0.06	5.17	—0.22 ± 0.06	3.67
	W		6.25 ± 0.03	+0.29 ± 0.05	5.80					—0.13 ± 0.05	2.60	+0.04 ± 0.05	0.80
Low-P	L	1.138	6.84 ± 0.04	—0.07 ± 0.06	1.17					+0.21 ± 0.06	3.50		
	W		6.01 ± 0.03	+0.05 ± 0.05	1.00					—0.11 ± 0.05	2.20		
High-P	L	1.152	7.05 ± 0.05	+0.14 ± 0.06	2.33							+0.09 ± 0.06	1.50
	W		6.12 ± 0.03	—0.16 ± 0.05	3.20							+0.17 ± 0.05	3.40
Low-K	L	1.150	6.90 ± 0.05	+0.01 ± 0.06	0.17							+0.24 ± 0.06	4.00
	W		6.00 ± 0.03	+0.04 ± 0.05	0.80							+0.29 ± 0.05	5.80
High-K	L	1.135	7.14 ± 0.04	—0.23 ± 0.06	3.83								
	W		6.29 ± 0.03	—0.33 ± 0.05	6.60								

*L and W designate tuber length and width.

TABLE 4—*General weather conditions* at Lakin, West Virginia and vicinity during the 1933, 1936 and 1939 growing seasons*

Year	March	April	May	June	July	August
1933	Cold and wet for farm work Flood conditions in Ohio Valley Unfavorable	Warm — excessive rains Planting retarded Unfavorable	Unusally warm Potatoes planted, but late Unfavorable	Extremely hot and dry Potatoes drying up Unfavorable	Cool — increased rainfall — potato yields low in section Much of crop dug Unfavorable	Cool — plentiful rainfall Favorable
1936	Warm — Very wet Flood condition in Ohio Valley Field preparation late Unfavorable	Unusually cool and cloudy — farm operations delayed first half of month Unfavorable	Warm — unusually dry particularly in last 10 days: Crop growth generally slow Potato crop poor Unfavorable	Driest month on record — 12 to 15 days without rainfall — insufficient rainfall Unfavorable	Much sunshine Most of rainfall in last 8 days. Very hot — rainfall insufficient Unfavorable	Decidedly warm rainfall below normal — Potato crop poor Unfavorable
1939	Generally favorable for crop growth Favorable	Generally favorable for crop growth Favorable	Conditions somewhat unfavorable Dry but not severe	Generally favorable to growth Favorable	Exceptionally cool—rainfall sufficient Favorable	Very dry—moderately warm — first of month favorable but last part dry Favorable

*Taken from Monthly Climatological Reports, West Virginia Section, Weather Bureau, U.S.D.A.

In these studies potash apparently had little effect on shape under unfavorable growth conditions, but contributed more to width under favorable conditions. This, in general, is in agreement with the findings of the other investigators mentioned.

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INFLUENCE OF SPROUTS ON PLANT EMERGENCE, GROWTH, TUBER-DEVELOPMENT AND YIELD OF POTATOES[1]

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In connection with a study of the effect of light and temperature during storage on the subsequent growth and yield of the potato it became evident that sprouts planted attached to the seed tuber had an important influence on time of plant emergence, time of growth and maturity, and usually on yield. Seed tubers, which were sprouted in light or in dark, in controlled storage at about the same temperature and relative humidity prior to planting, gave equally good response.

Two experiments were conducted in 1939. The object of the first was to study tuber set and development in relation to time of plant emergence and growth as influenced by sprouts on the planted seed. The object of the second experiment was to determine why the removal of short sprouts in comparison with no removal, delayed plant emergence, growth and maturity. Two explanations of the latter results seemed plausible. First, removal of sprouts may have brought about a serious loss of food reserves or growth substances, and second, re-

[1]Published as Paper No. 207, Department of Vegetable Crops, Cornell University, Ithaca, N. Y. The author is indebted to Dr. Ora Smith for suggesting and directing these studies.

moval of sprouts, being a pruning operation, the tubers would have to produce new sprouts before plant emergence could occur.

This paper reports the results obtained in these experiments.

Results of Experiment I

Certified No. 2 size tubers of the X89 strain of the Smooth Rural Variety were moved from common storage at 40°F., on the 15th of March to the controlled storage at 36°F. Tubers weighing from 40 to 60 grams each were selected on the 3d of April, one-third of them being left in storage at 36° and the others placed in controlled storage at 40°. On the 6th of May seed in storage at 40° was moved to controlled storage at 50°, divided into two lots, one lot exposed to continuous light of one 150-watt bulb, and the other lot placed in the dark. The air temperature averaged 50.5° in the light and 51.4° in the dark; whereas the relative humidity averaged 84 per cent in the light and 88 per cent in the dark. Also, on the 6th of May seed in storage at 36° was divided and given similar light and dark treatments. Air temperature averaged 35.9° in the light and 35.95° in the dark and relative humidity averaged 95 per cent in the light and 93 per cent in the dark.

Light was arranged in each storage so that surfaces of the seed exposed to light received an average intensity of 40 foot candles. The duration of the treatment was for a period of one month. Thermocouple records showed that tissue of tubers exposed to the light absorbed heat and was approximately 1.5° F. warmer than tissue of tubers kept in dark in each storage.

At the end of the treatment, seed in light in warm storage was dark green to purplish-black in color and had green sprouts ¼ to ½ inch in length. The seed in dark was normal in color and had white sprouts ½ to one inch in length. On the 4th of June all sprouts were removed from one-half of the seed sprouted in light and from one-half of those sprouted in dark. Seed stored in the light or in the dark in the cool storage showed no visible sprouts. Those exposed to light showed no green color. Upon further examination, however, some chlorophyll was found in plastids of cells beneath the periderm.

The soil used for the experiment was a gravelly loam of medium fertility. A 5-10-5 fertilizer was applied in the row, 1000 lbs. to the acre. On the 5th of June one hundred and twenty uncut tubers of each treatment were planted one foot apart in the row and covered to a uniform depth. Tubers of the several treatments were in adjacent rows,—spaced 34 inches apart.

TABLE I.—*Influence of sprouts on plant emergence and maturity*

Storage	Number of Days after Planting June 5, 1939												
Treatment	16	19	22	25	30	33	39	45	47	110	115	121	129
	Per Cent of Plants above Ground									Estimated Per Cent Dead Leaves			
Stored in light													
Sprouted	29	83	100							45	65	90	100
Desprouted			24	78	100					12	25	50	80
Dormant				3	31	54	87	100		0	5	15	35
Stored in dark													
Sprouted	47	93	100							50	75	95	100
Desprouted			17	73	100					12	25	50	80
Dormant				2	34	68	79	95	100	0	5	15	35

Marked differences were found in the time of plant emergence, as shown in table 1. The plants of sprouted seed came up first, those of desprouted seed emerged next and those of dormant seed appeared last. Sprout removal in comparison with no removal definitely delayed plant emergence.

In this table you will note that the time of plant maturity was correlated with the time of emergence, plants emerging first matured first, etc.

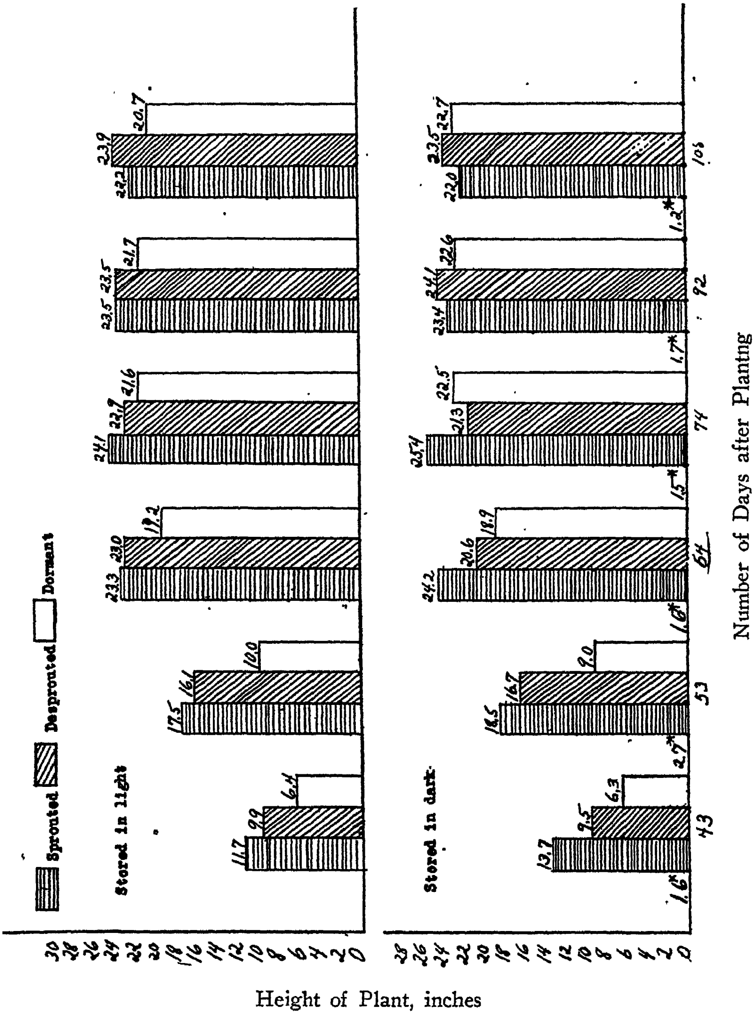

Figure 1:—Height of plants in inches.
*Least difference for odds of 19:1. Each least difference applies to the corresponding three bars of the upper and the lower portion of the figure.

Seven harvests of 10 plants of each treatment were made, the final harvest being 3 days after killing frost. The height of each plant after being cut off at the soil surface, the total number and weight of tubers and the number of stems at the seed tuber were recorded. Individual plant records were used as replicates and the data treated statistically by the analysis-of-variance method.

Forty-three days after planting, all plants of sprouted seed had blossom buds, whereas 80 per cent of those of desprouted and 15 per cent of those of dormant seed had blossom buds.

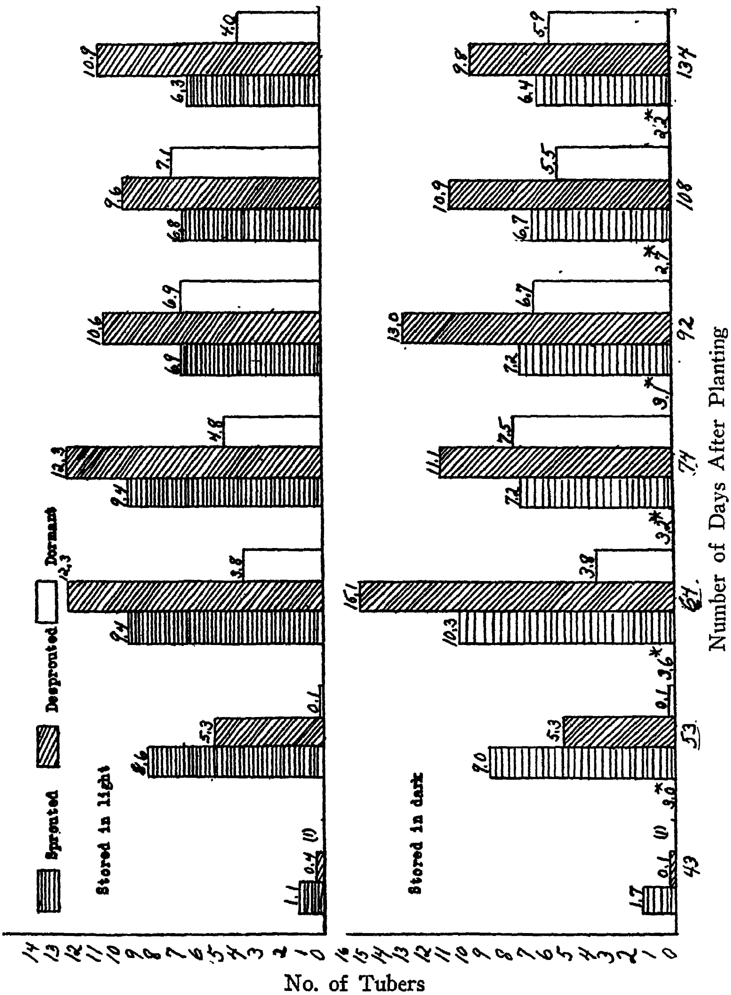

Figure 2:—Time of Tuber Set.
*Least difference for odds of 19:1. Each least difference applies to the corresponding three bars of the upper and the lower portion of the figure.
(1) Too small to weigh.

At the first harvest, as revealed in figure 1, the plants of sprouted seed were significantly taller than those of desprouted and dormant seed. Also plants of desprouted seed were significantly taller than those of dormant seed. Fifty-three days after planting, plants of sprouted and desprouted seed were not statistically different in height, whereas plants of both of these treatments were significantly taller than plants of the dormant seed. The plants of sprouted and desprouted seed almost attained their maximum height 64 days after planting, whereas those of the dormant seed did not attain this stage of development until 74 days after planting. Although some significant differences in height of plant were found between treatments 74, 92 and 108 days after planting, they were small in magnitude.

The data in figure 2 indicate that tuber set occurred first on plants of sprouted, next on those of desprouted, and last on those of dormant seed. This was in order of emergence, attainment of blossom stage and maximum height of plant. Other interesting relationships are shown.

Although the plants of desprouted seed set tubers slightly later than those of sprouted seed, they had the larger number of tubers 64 days after planting and at every harvest thereafter,—and the differences were statistically significant. Also the plants of desprouted seed had more tubers than those of dormant seed 53 days after planting and at every harvest thereafter. The differences, except with seed stored in light 108 days after planting, were statistically significant. The plants of sprouted seed, with few exceptions, produced more tubers than those of dormant seed. The differences, however, were statistically significant only at the 2d, 3d, 4th, and final harvest with seed stored in light, and at the 2d and 3d harvest with seed stored in dark.

Rosa (4) and others have shown that as the number of stems per plant increases the yield in number of tubers per plant increases. On this basis, the data in table 2 explain the large number of tubers produced by the desprouted seed. Appleman (1) and Bushnell (2) have shown that sprout removal decreases apical dominance and increases the number of stems per seed piece. Pruned stems usually produce a larger number of stems, from the point of cutting onward, than that which existed prior to pruning. Since potato tubers are stems, similar results would be expected of desprouted tubers. This occurred (table 2) whether the tubers were sprouted in light or in dark, before desprouting.

Sprouted seed, owing to storage at higher temperature, had significantly more stems per seed tuber than dormant seed as shown in table

TABLE 2.—*Influence of sprouts on number of stems per plant*

	Storage Treatment					
	Stored in Light			Stored in Dark		
	Sprouted	Desprouted	Dormant	Sprouted	Desprouted	Dormant
Stems per plant*	1.67	2.46	1.21	1.78	2.70	1.26
Least Difference†	.23					

*70 plants of each treatment considered. †Least difference for odds of 19:1

2, and tended to produce more tubers. This is in agreement with results reported by Smith (5).

No markedly significant differences existed in the number of stems per seed tuber as between light and dark stored seed. Bushnell (2) found that seed sprouted in light had fewer stems per seed piece than those sprouted in dark and desprouted before planting. In other experiments, in which the seed stored in dark was not desprouted, he found no difference in number of stems. From the former test he concluded

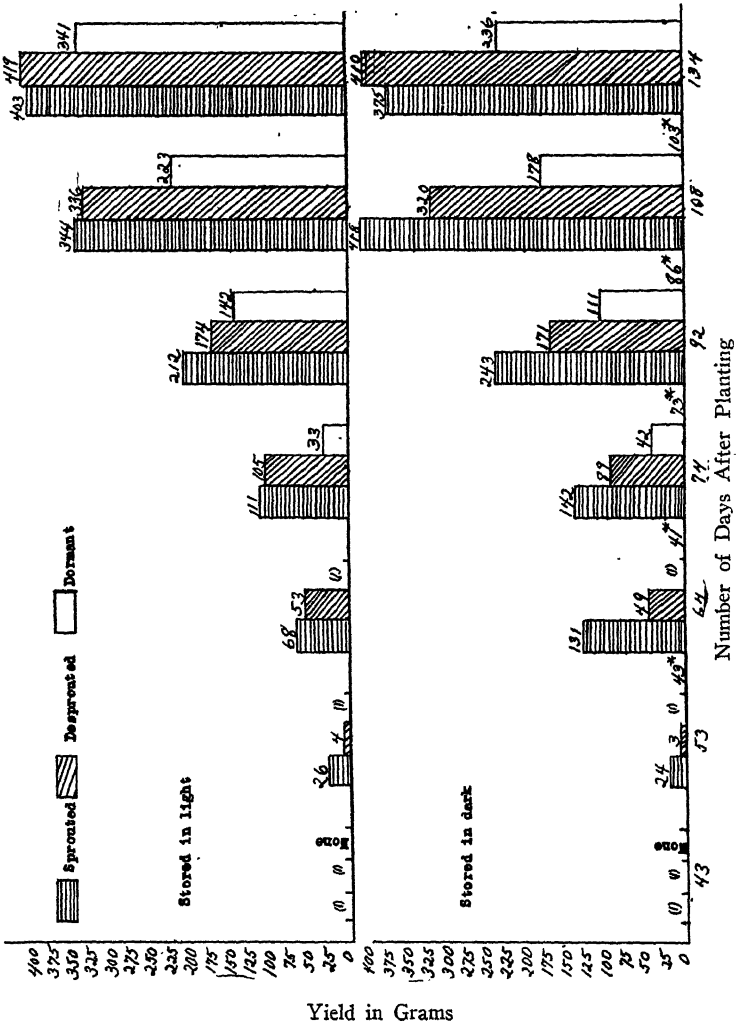

Figure 3:—Yields in grams.
*Least difference for odds of 19:1. Each least difference applies to the corresponding three bars of the upper and the lower portion of this figure.
(1) Too small to weigh.

that under the conditions of light and temperature employed, light retarded physiological processes leading to multiple sprouting, whereas from the latter experiment he concluded that light did not influence the number of stems. Hardenburg (3) in field comparisons of green-sprouted and dark-stored desprouted seed found fewer stems per seed piece on those exposed to light. He concluded that greensprouting decreased the number of stems per seed piece. These workers did not have comparisons in which seed sprouted in light was desprouted before planting. Results of the present study indicate that exposure of tubers to light did not decrease the number of stems per seed piece as these workers conclude, but that sprout removal from seed stored in the dark resulted in a greater number of stems per seed piece.

The yields in weight as shown in figure 3, except at the final harvest, were correlated with the time of plant emergence and growth. Yields were highest with sprouted seed, lowest with dormant and intermediate with desprouted seed, although the differences were not statistically significant in all comparisons.

Yields at the final harvest, as between sprouted and desprouted seed were reversed, although the differences were not statistically significant. This was no doubt, owing to the fact that although plants of sprouted seed emerged earlier than those of desprouted seed, they also matured earlier. If total number and weight of tubers produced by sprouted and desprouted seed are considered, the latter yielded tubers of lower average weight.

At the final harvest the yield was lower from dormant than from sprouted or desprouted seed. With seed stored in light, the differences were not statistically significant. With seed stored in dark, the difference was significant in both comparisons.

Results of Experiment 2

When tubers were selected on the 3rd of April for experiment 1, two lots of tubers each weighing 40 to 60 grams were selected from the same stock, for experiment 2. These were stored at 40° F. On the 3d of May, lot 1 was stored in dark at 75° and by the 16th of May sprouts averaging 1.21 centimeters in length had developed. The sprouts were removed and the tubers left in this storage to produce a second crop of sprouts.

Tubers of lot 2 were placed beside those of lot 1 to sprout on May 16th. On May 30th the sprouts on tubers of lot 1 averaged 1.53 centimeters in length and those on tubers of lot 2 averaged 1.15 centimeters in length.

On the 31st of May tubers of the two lots were planted, without cutting, and with sprouts attached, in two rows adjoining those of experiment 1. The seed tubers were spaced 2 feet apart in the row. The spaces between rows and fertilizer application were the same as for experiment 1.

Seed tubers with one crop of short sprouts removed and planted with a second crop attached, produced plants above ground as early as seed planted with the first crop of sprouts (table 3). Plants from the seed which was sprouted twice also matured as early as those of seed sprouted only once. This indicates that the delay in plant emergence when desprouted tubers were planted immediately after the desprouting operation in experiment, was because of loss of sprout as a plant part rather than to loss of food reserves or growth substances in the sprout.

The plants were harvested 135 days after planting. The records in table 4 show no significant difference in yield of number and weight of U. S. No. 1 size or in total weight. However, the seed which was sprouted the second time, because of one desprouting, produced a signficantly greater number of stems per seed piece, and a significantly greater total number of tubers per plant.

Summary and Conclusions

Sprouted seed produced plants above ground earlier than desprouted seed and much earlier than dormant seed.

Subsequent plant growth as measured by increase in height of plant, attainment of the blossom stage, time of tuber-set, increase in weight of tubers, and time of maturity, was in the order of emergence.

The largest number of stems per seed tuber was produced by tubers which were desprouted prior to planting. This was owing to the desprouting operation. Sprouted tubers produced a larger number of stems per seed tuber than dormant tubers, because they were stored at the higher temperature.

The largest number of tubers per plant was produced by the seed which had the largest number of stems per plant.

The data of experiment 1 indicate that the final yield in weight of tubers from sprouted, desprouted, and dormant seed would depend primarily on time of planting, length of growing season and climatic conditions. With early planting, or a growing season sufficiently long to permit plants of the three seed treatments to attain complete maturity, under equally favorable climatic conditions, yields would, no doubt be equal. With late planting or a short growing season, in which the

TABLE 3.—*Influence of sprout treatment on plant emergence and maturity.*

Storage Treatment	Number of Days after Planting May 31, 1939									
	19	20	23	25	116	119	121	125	127	131
	Per Cent of Plants above Ground				Per Cent of Plants Dead					
Stored in dark										
Lot 1. Sprouted twice	54	82	98	100	1.0	2.0	2.0	31.0	52.0	55.0
Lot 2, Sprouted once	38	47	94	100	0.5	0.6	1.0	15.2	36.3	42.0

TABLE 4.—*Influence of sprout treatment on number of stems and yield per plant*

Treatment	Tubers Planted	Stems	Yield of U. S. No. 1 Size		Total Yield	
	Number	Number	Number	Pounds	Number	Pounds
Stored in dark						
Lot 1, Sprouted twice	65	2.51	4.34	1.39	8.65	1.58
Lot 2, Sprouted once	66	1.79	4.17	1.48	7.12	1.62
Difference		.72*±.16†	.17±.22	.09±.07	1.53*±.57	.04±.06

*Significant. †SE of the difference.

plants of all seed treatments were killed by frost before maturing, yields would probably be highest from sprouted and lowest from dormant seed.

The relative response of sprouted, desprouted, and dormant seed was the same whether they were stored in light or in dark for one month before planting.

Data are presented which indicate that delay in plant emergence, subsequent growth, and maturity resulting from removal of short sprouts, in comparison with no removal is caused by loss of the sprout as a plant part, rather than to loss of food reserves or growth substances in the sprout.

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EFFECT ON BERRY PRODUCTION OF VARIED DAY LENGTH DURING THE LIFE OF TWO TRIUMPH POTATO STRAINS[1]

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With a 16-hour photoperiod and 20-30 foot candles of supplementary light, induction of flowering in Triumph potatoes was a failure (2). However, the response of the plants in the lots receiving supplemental light for 35 days indicated that they were not receiving enough light for satisfactory blooming, and that better results might have been procured by using longer days or more light. In the earlier part of the 1939-'40 season, our work indicated that there might be a possibility of inducing blooming by using a very bright light in a long photoperiod for a short time without the necessity of continuing either, to bring about both flower production and berry formation (3).

[1]Published with the approval of the Director of the Nebraska Agricultural Experiment Station, as Journal Series No. 284.
[2]Professor of Horticulture.

TABLE I.—*Number of berries and weight of tubers per five plants of each lot of two strains of Triumph that were grown with two photoperiods for different periods of time*

Lot No.[1]	Days When Supplemental Light Was Used	Berries Produced with Photoperiods of				Tubers Produced with Photoperiods of			
		24 Hours		18 Hours		24 Hours		18 Hours	
		T 12	T 22	T 12	T 22	T 12	T 22	T 12	T 22
		No.	No.	No.	No.	Gm.	Gm.	Gm.	Gm.
1	None	0	0	0	0	559	447	538	419
2	1-20	0	7	0	4	534	427	493	415
3	1-30	0	2	0	6	479	508	489	421
4	1-40	2	10	0	9	476	441	413	533
6	1-50	0	7	0	8	612	532	454	425
8	1-60	0	21	0	6	494	433	588	473
10	1-70	9	33	0	10	461	396	543	456
11	11-70	21	18	0	6	483	466	481	44
5	31-40	0	0	0	0	686	429	518	468
7	31-50	0	0	0	1	624	513	484	485
9	31-60	0	8	0	0	749	497	617	488
12	31-70	5	15	0	5	719	588	622	631

[1]Lots arranged in order of time of application of supplemental light in the lifetime of the plants.

A series of tests were conducted wherein some seed pieces were planted in a humid atmosphere in the light so that all sprout growth would take place in light of given intensity and duration. This light treatment was continued for 20, 30, 40, 50, 60, and 70 days after planting. In other sets the light treatment was started on the 11th and 31st days and continued for various numbers of days as is shown in table 1.

The seed pieces were planted on the 29th of December and transplanted in gravel in gallon cans (1 plant per can) on the 30th of January when the light treatments were started. Five plants of T12 (very early Triumph) and five of T22 (midseason Triumph) were used in each set for both 18 and 24-hour photoperiods. A complete nutrient solution was supplied three times per week or more frequently. The supplemental light intensity ranged between 200 and 250-foot candles at the tops of the plants throughout the test periods. Pollen from fertile lines growing elsewhere was used on these flowers.

Results

The very early strain of Triumph (T12) produced flowers capable of producing berries in only four lots as shown in table 1. The best treatment was the one in which a 24-hour photoperiod was used from the 11th to the 70th day after planting (Lot No. 11). With it 21 berries were produced on the five plants. In the next best treatment a 24-hour photoperiod was used the first 70 days (Lot No. 10) and 9 berries were produced. The third treatment was the one using a 24-hour photoperiod from the 31st to the 70th day (Lot No. 12), and with this treatment only 5 berries were produced on the five plants (No. 12). Two berries per set were produced with 24-hour days for the first 40 days (No. 4). No berries were produced by strain T12; with the 18-hour day, in fact only a few buds, that aborted just before blooming, were produced in the 18-hour sets that had light for a period ranging from 60 to 70 days.

These results with strain T12 indicate that the use of long photoperiods, while the sprouts were developing, were of some consequence in developing flowers capable of producing berries, if the light were continued for a long time thereafter. It also indicated that if long photoperiods were used during a period beginning about 40 days before the first blossoms opened and continuing throughout the blooming season, fair results could be secured. None of these was equal to continuous illumination until the berries set.

The six additional hours of 200-250 foot-candle light used in prolonging an 18-hour to a 24-hour photoperiod were essential for any blooming with this strain.

With the midseason strain (T22) some berries were produced in all except three lots with each photoperiod. With the better treatments the response to a 24-hour day was always much better than an 18-hour day. With the poorer treatments there was very little difference between the two photoperiods.

Very good results were secured with strain T22 when a 24-hour period was used for the first 70 days (Lot No. 10, Table 1). When this photoperiod was used for the first 60 days, results were only about two-thirds as good (Lot No. 8) and just about one-half as many berries resulted when used from 11 to 70 days. The next best treatment was with long days from the 31st to 70th day (Lot 12). Some berries were secured when 24-hour photoperiods were used the first 20 days or longer (Lots 2, 3, 4, etc.), or from the 31st to the 60th day (Lot 9), but no berries were produced when the 24-hour photoperiod was used only for 10 or 20 days after the 30th day (Lots 5, 7). Apparently berries can be produced by using a long photoperiod only during the first 30 or 40 days (Lots 3, 4), but results are greatly enhanced if the use of light is prolonged to 60 (Lot 8) and still better, if prolonged 70 days (Lot 10). During the latter time the flowers have a chance to complete their development. When extra light was given for a 10-, 20-, or 30-day period just at the time flower primordia were initiated or starting to develop (Lots 5, 7, 9) it was of little or no value, but if prolonged to 40 days through the flower-developing period (Lot 12), it was very useful.

Apparently if only 40 days of long photoperiods are to be used, the best time is from shortly after plants have emerged until the blooms are fairly well developed. Less than 40 days of light was never satisfactory. While the sprouts are developing, light is very useful, but may not be essential for obtaining some flowers if used when flowers are in the final stages of development.

With an 18-hour photoperiod, berries were produced under practically all conditions, as with 24 hours, but berry production did not increase as much with the combinations that gave the better results when 24-hour days were used.

In considering the merits of supplemental light during the first 60 days consideration must be given to the fact that when these tests were conducted the late January light (13th to 27th) was relatively very good, whereas the February and early March light was not so good as in most years. The low daylight values in early March when flowers were opening may account for the very good results secured when long

photoperiods were extended from the 60th to the 70th day. Parker and Borthwick (1) have recently shown that a certain minimum daily photo-synthetic activity is necessary for induction of flowering in Biloxi soybeans.

Our data do not show any significant differences or trends of tuber yields, except that when plants were grown in a long photoperiod for an increasing number of days starting with the 31st, there was a slight tendency for tuber production to increase.

Summary

With an intermediate strain of Triumph potatoes (Triumph 22), the continual use of long photoperiods until pollination time resulted in the most berries.

When long photoperiods were used during relatively short intervals in the life of the plants, they appeared to be most useful when the flowers were making their final development.

Long photoperiods very early in the life of the plant were very useful for berry production, but were not indispensable and unless the long photoperiods were continued for 60 or 70 days they brought about the production of relatively few berries.

Berry production occurred with an 18-hour photoperiod, but production was only one-third as great as with a 24-hour photoperiod.

No berries were developed by the very early strain (Triumph 12) with an 18-hour photoperiod and with this strain berries were produced with only four of the 24-hour photoperiod treatments.

Our evidence indicates that induction of flowering in Triumph potatoes by using long photoperiods for short intervals of time is not feasible and except under very favorable conditions of high light intensity it is not possible.

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REDUCED TOXICITY OF CUPROUS OXIDE TO *PHYTOPHTHORA INFESTANS* (MONT.) DEBARY BY THE ADDITION OF CERTAIN INSECTICIDES

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A dust combination that would give effective insect and disease control in one operation would be of definite advantage to potato growers. Experimental work along this line has now been conducted for four years on Long Island where, for various reasons, there is a particular need for such a program. These trials to date have centered largely in various combinations of pyrethrum, rotenone, sulfur, and cuprous oxide. Information on insect control has been obtained every year, but this past season gave us the first opportunity to study the effect of some of these dust combinations on late blight control. The data obtained appear to be rather clear cut and of sufficient importance to present at this time.

The results to be presented were obtained from a large-scale field experiment in which the 6-row plots were dusted six times during the growing season with power dusting equipment. The experiment was one of factorial design involving all possible combinations of pyrethrum, rotenone, sulfur, and cuprous oxide*. The dust mixtures were prepared just prior to the start of the experiment and were used throughout the season.

Blight counts were made on two separate dates on the plots dusted with the copper-containing dusts (Table 1). It is evident from

TABLE 1.—*Counts of late blight lesions on potato plants dusted with various insecticide-fungicide combinations*

Dust Combinations	Lesions per 5 Plants		Total Lesions Per 10 Plants
	July 20	July 27	
Cuprous oxide alone	38	65	103
Copper + rotenone	282	358	640
Copper + pyrethrum	356	477	833
Copper + rotenone and pyrethrum	361	436	797
Copper + sulfur	146	311	457
Copper + sulfur and rotenone	210	285	495
Copper + sulfur and pyrethrum	328	500	828
Copper + sulfur, rotenone and pyrethrum	195	218	413

*The finished dusts were prepared to contain the following concentrations of active ingredients: pyrethrum, 0.05%; rotenone, 0.75%; sulfur, 35%; cuprous oxide, 5.16%. Bancroft clay was used as the diluent.

these data that the addition of certain materials to cuprous oxide resulted in an increase in blight lesions, *i.e.*, an apparent reduction in toxicity of the copper. An analysis of these data as a factorial experiment shows, however, that only in the case of pyrethrum was the increase in blight counts significant (F value 57.2). Interestingly enough, all the first order interactions are significant with odds exceeding 100:1. This apparently arises from the fact that the addition of any two of these materials to cuprous oxide does not give an increase in blight count corresponding to the sum of these two materials when used independently, but rather some value lower than this. (Note column on treatment effects in table 2).

TABLE 2.—*Analysis of treatment effects*

Effects	Increase or Decrease in Total Lesions	Variance	F Value	1 Per Cent
Main;				
Rotenone	+ 124*	961.00		
Pyrethrum	+1176	86,436.00	57.2	11.3
Sulfur	— 180	2,025.00		
Dates	+ 734	33,744.75	22.3	"
Interaction:				
Rotenone and pyrethrum	—1026	65,792.25	43.5	"
Rotenone and sulfur	— 878	48,180.25	31.9	"
Pyrethrum and sulfur	— 598	22,350.25	14.8	"
Error		1,511.8437		

*Significance level 1% = 513.2 lesions.

From similar experiments in the past (1) it was concluded that in no case did the addition of cuprous oxide reduce the toxicity of the insecticide used. The effect therefore, that these insecticides have on the toxicity of cuprous oxide is an interesting one and may involve some practical significance, since commercial firms and others are apparently interested in preparing just such mixtures. How pyrethrum and rotenone from different sources and different diluents would affect the several types of insoluble coppers is still an open question.

Doctors Heuberger and Horsfall of the Connecticut Agricultural Experiment Station have conducted an interesting investigation on the reason for the decreased fungicidal value of copper-rotenone and copper-pyrethrum mixtures and their data lend excellent support to our rather limited field data.

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SECTIONAL NOTES

ALABAMA

The Alabama 1941 potato deal nears its end. It has been marked by variety both in seasonal extremes and price fluctuations.

Both the early part and the middle part of the growing season were characterized by a good distribution of rainfall, but other climatic conditions caused about a two-weeks' delay in the maturity of the crop. During the latter part of the growing season rain was below normal and maturity was again somewhat delayed and yields partly reduced.

The early harvested potatoes were somewhat under size, but as the season advanced the tubers developed quite a satisfactory size. The quality of the crop has been excellent throughout the season.

Production will probably reach 7,500 cars as compared with the 8,000 to 9,000 predicted earlier in the season.

For a while prices were disappointing. At one time No. 1 potatoes sold as low as 80 cents per hundred, but by the first week of June prices had swung back to 1.40 to 1.50 per hundred.

Approximately 6,000 cars were moved by the 6th of June. About 1,200 to 1,500 cars still remain to be moved. (June 11).—L. M. WARE.

CALIFORNIA

The ring rot problem in Kern County is not so serious this year as in past years. This is probably caused by two factors. (1) The growers were more particular about purchasing seed which was free from ring rot and, of course the seed producers were more particular last year about the seed they planted. (2) Our weather conditions here have been quite cool for the harvesting of a large percentage of our crop, and this probably has resulted in a slower development of the disease.

Early and late blight have caused considerable damage. The early blight is still reducing the yields, as it is continuing to spread in practically all the fields. There has been some check in its spread during the last week or two. The late blight, however, did considerable damage to our plants in the early portion of the season and also caused considerable loss to tubers in transit. Railroad companies reported cars being abandoned to them in transit.

The total shipment of potatoes by rail from Kern County this year to date is 5,684, as compared with 7,382 on the same date last year. It now appears that we may be in the neighborhood of 3,000 cars short

in rail shipments this year as compared with last year, despite the fact that this year we have planted approximately 3,000 acres more than we planted in 1940. The price of potatoes at the present time, f.o.b. Shafter, is ranging from $1.50 to $1.65 per hundred for U. S. 1's. Growers are anticipating that this price will continue to rise. If prices should continue to rise probably some of the growers will leave their crop in the ground for a longer period. This, of course, will create a slightly greater yield than if the price were lower. (June 5).—M. A. LINDSAY.

INDIANA

The prospects for a good yield of early potatoes of high quality are very promising. The ground was well prepared before planting and is in excellent condition at the present time. Although rainfall has been spotted and light in some sections, the weather has been cool and otherwise quite favorable. There was some frost damage on the early plantings but the vines recovered and are apparently making strong growth and a heavier set of tubers.

A few growers are harvesting for local trade but the majority will hold off until the latter part of the month and place the bulk of the early crop on the market during July and the early part of August. The use of certified seed is increasing and, in some sections, a carload of seed was used compared with 50 or 60 sacks a year ago. Most of the plantings are Cobbler with here and there a few acres of Bliss and Ohios. We also find more interest in irrigation in the early southern area, with one grower applying water to 40 acres for the first time and, as a result, there is a great difference already noted in the set and plant growth.

There was only a light attack of bugs this year and timely control measures destroyed the pests in a hurry. Late plantings are in for the most part and ready for the first cultivation. Our total acreage will be higher this year than in 1940. (June 10).—W. B. WARD.

MICHIGAN

On June 1st most of the growers in the Upper Peninsula of Michigan had nearly completed their plantings. Most of the early crop was planted earlier than usual because of the early spring. However the later crop in the lower Peninsula is probably less than one-half planted to date,—the 11th of June.

A much larger part of Michigan's certified seed crop was purchased in the state this year by the tablestock growers.

The intended acreage to plant has been somewhat changed during the past months; first, because of the fear of labor shortage; and second, increased plantings of beans which will replace some of the potato acreage.

The certified seed plantings are about normal, with a slight reduction in Russets replaced by Chippewas.

The Potato Field Day which is held at the Potato Experiment Farm at Lake City has been drawing such large crowds in the past that two days are felt necessary in order to give ample time for all phases of the potato program. The dates scheduled will be the 20th and 21st of August. (June 11).—H. A. Reiley.

MINNESOTA

Potato planting in the sand land area got off to a good start early in April under very favorable conditions. Growing conditions since that time have been almost ideal and we have reports that digging may start by the 25th of June. This is approximately three weeks earlier than usual.

Conditions in the Red River Valley and in the northern part of the state where potato planting starts about the first week in May and continues to the first week in June have not been so favorable. During the latter part of April and early May many fields were so wet that the seeding of grain was delayed. Further heavy rains occurred in the Valley after the grain had gotten a nice start and these rains also delayed potato planting. Potato planting is now practically completed except on the peat bogs in the north central section of the state where heavy rains, since the middle of May, have prevented the growers from getting into the fields. Unless the bogs dry up sufficiently to permit getting on the fields within the next three or four days it is questionable whether it will be wise to plant potatoes on this type of soil so late in the season.

In the Hollandale peat section, potato planting got off to a good start and reports indicate that the crop is coming along in fine shape.

A number of applications for certification inspection have been sent in. Applications will be due by the 15th of June, but owing to the excessive late rains in certain seed-growing areas, we will have to extend the final date for receiving applications. For years we have been advocating the importance of growing isolated tuber-unit seed plots for the purpose of certification planting and there has been an increasing interest in this type of work. Much of the stock planted for certification

inspection this year comes from such plots and many of the larger fields which we will inspect are being planted on the tuber-unit basis. (June 9).—A. G. TOLAAS.

NEBRASKA

The intentions to plant certified potatoes in Nebraska show 10 to 15 per cent reduction compared with the acreage planted in 1940. During the past three years, there has been a gradual increase in acreage entered for certification, and the reduction will probably bring the acreage just a little below the average for the past ten years.

The crop in 1940 was one of the largest on record, being exceeded slightly in yield by the 1930 crop.

Planting conditions are excellent through the territory, as general rains were received during the last week of May and the first week in June. Growers report that there is ample moisture to start the crop,—a condition that has not been true for several years.

Planting has just begun, with a few growers starting on the first of June, whereas the majority seldom start until the 10th. The crop should be practically planted by the 20th, barring unfavorable weather conditions. (June 9).—MARX KOEHNKE.

NEW JERSEY

The climatic conditions during the past three weeks have been very favorable. Most sections have had sufficient rainfall and the temperature has been low, resulting in excellent plant growth. Many crops are in full bloom and the plants have made a good set of tubers. Until this week few insects have been noted. If our weather continues favorable our growers should experience excellent yields. If present prices do not decline rapidly, some growers will start harvesting operations in July.

Present indications are that the potato dealers of Central New Jersey will organize a central sales organization for handling this year's crop. Under this plan all potatoes will be sold from a central office in order to stabilize prices. This operation will be similar to the plan adopted in 1933, when nearly three million dollars worth of potatoes were sold in approximately ten weeks. (June 14).—JOHN C. CAMPBELL.

NORTH CAROLINA

Owing to the extremely dry weather during May and the early part of June our early potato crop has been reduced from 35 to 40 per

cent. It is estimated that we will ship about 5,000 cars this year, whereas last year we shipped 8,044.

Compared with last year we are, at the present date, behind in our harvesting and shipping. Growers have been waiting for rain in order to give the crop a longer period in which to grow. (June 12).—ROBERT SCHMIDT.

OHIO

The weather in Ohio was quite cold until the first part of April. Therefore very few potatoes were planted until that time. Throughout April and May the temperatures were above normal, with very little rainfall. The early potatoes were planted in record time and the soil was in excellent condition. The southern part of the state was suffering from the lack of moisture until the latter part of May. Since that period there has been ample rain. Although the rainfall was below normal, the crops in the northern section of the state did not suffer so much as did those in the southern portion.

The stands of the early crop are exceptionally good and the rains during the past two weeks have improved the crop so much that at the present time, prospects look better than they have for years. The acreage is about the same as last year except that more Cobblers, Katahdins and Chippewas have been planted, replacing more of the Russet acreage. Our late crop is, at present, practically planted.

Our State Potato Day will be held at the Ohio Agricultural Experiment Station, Wooster, Ohio, on Tuesday, the 12th of August. (June 13).—EARL B. TUSSING.

PENNSYLVANIA

The potato crop in this state looks very promising at this early date (June 13). Weather conditions during May were very dry and generally unfavorable. Germination was rather uneven and the plants made very little growth. General rains on the 4th and 5th of June, however, supplied some much needed moisture with the result that today potato fields are in excellent condition. The rains of the 12th of June also helped the crop. Many of the earlier planted crops are in bloom, and with favorable growing conditions for another month, Pennsylvania growers will harvest a good crop of early potatoes.

There was a marked trend in demand for Russet Rural seed this past spring. Although the demand for Katahdins was good it is thought that growers decreased their planting of both Katahdins and Chippewas and possibly fewer Cobblers. Houmas and Sebagos are being quite extensively tested.

Applications for seed certification are being received. We anticipate a considerable increase in the acreage entered for certification compared with that of 1940. (June 13).—K. W. LAUER.

SOUTH CAROLINA

South Carolina potato growers will finish digging their crop this week. Usually, harvesting is completed by the latter part of May but this year cold weather in January and February delayed emergence of the plants whereas dry weather during much of the growing period prevented normal growth and development. The rainfall for May was .07 inches as compared with a normal rainfall for that month of 3.00 inches.

Although an increase in acreage was reported for South Carolina, present indications point to the fact that production of U. S. No. 1 potatoes will be only two-thirds of last year's crop. The yields on some farms have been very good, running as high as 150 sacks of No. 1 potatoes per acre, but many growers are making less than 50 sacks. This is especially true on the lighter soil types where drought reduced the yields of No. 1's and resulted in a proportionate increase in No. 2's and 3's.

The quality of the crop has been very good. Growers have experienced dry weather during the harvest period and have been digging bright, clean potatoes. One or two washers and dryers are in operation in Charleston county but only a small part of the crop is being washed.

Several growers irrigated their potato crops this season with portable irrigation systems. One man used water from a deep well whereas others pumped from the Edisto River at points above salt water. A reported yield of 125 to 150 sacks per acre was obtained from irrigated fields whereas adjoining farms, not irrigated, made 50 sacks or less. Yields, in this case, would probably have been somewhat greater if a pump with a larger water capacity had been available to supply more water. Many vegetable growers in this area would put in irrigation systems if satisfactory water supplies were available to them. Although deep wells could supply an adequate amount of water it is often too salty for irrigating vegetable crops, and most of the streams in the potato-growing sections along the coast are tidal and too salty.

Dry weather has made it possible for us to observe the relative drought resistance of different varieties. If the term "drought-resistance" is understood to mean the ability of a variety to produce a relatively good yield of No. 1 potatoes under very dry conditions then Pontiac and Chippewa, as well as several U.S.D.A. seedlings, may be

termed "resistant to drought." Pontiac has outyielded Bliss Triumph in a number of tests whereas Chippewa has given high yields compared with Irish Cobbler and other white varieties. (June 9).—MITCHELL JENKINS, JR.

SOUTH DAKOTA

Potato planting has been completed with approximately a 20 per cent increase in the certified acreage compared with 1940 when 1,800 acres were entered for certification. Our acreage of commercial stock will show a decrease from last year. Early potatoes have been cultivated and, at present, show a very good stand.

Earl P. Barrios, Jr., a graduate of the Louisiana State University, will again act as field inspector for the association, starting work about the 12th of June. Three roguing schools will be held to train men to rogue potatoes.

Soil conditions are ideal with plenty of rain in most of the territory. The annual tour of the association will be held during the week of the 14th of July.

Growers are now arranging for their spraying and dusting material, in order to have it on hand before needed. Very few Colorado beetles have been found in South Dakota fields in the past few years, but spraying is practiced in order to control leafhoppers and blister beetles. (June 9).—JOHN NOONAN.

VIRGINIA

During the latter part of May our climatic conditions were decidedly detrimental to the potato crop throughout the eastern Virginia area. From the 16th to the 31st of May temperatures in excess of 90 degrees were recorded for ten days and on two days the temperatures were 100 and above. The rainfall during the entire month of May, recorded at the Virginia Truck Experiment Station, was only .85 of an inch. Since the subsoil moisture had already been practically depleted during the dry weather in April, the effect of this heat and drought has been quite serious to the potato crop. The weather has been much more favorable during June. Rainfall from the 1st to the 14th of June has been slightly more than 2 inches in most of the potato area, although some limited areas have not yet had sufficient rain to be of any appreciable benefit.

It is difficult to estimate the yield of potatoes accurately because the showers which have fallen in the potato areas were rather scattered until the 13th of June when approximately an inch of rain fell

over most of our potato area. On the average it is believed that the condition of the crop at present is not more than 50 per cent of normal and that the yields will be exceedingly light.

A few potatoes started moving from the Eastern Shore this week but it is expected that the peak movement from Virginia will not start until after the 1st of July. Diggings to date have produced only about 20 barrels of primes per acre. Undoubtedly some fields will yield considerably heavier than this because of the benefits of recent rains, although other fields which are badly damaged will not produce even as much as 20 barrels per acre. Most of the crop will be shipped in 100-pound bags but barrels will be used to some extent for shipment from the Eastern Shore. (June 14).—H. H. ZIMMERLEY.

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REDUCTION OF CRACKING OF LATE CROP POTATOES AT HARVEST TIME BY ROOT CUTTING OR VINE KILLING

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Potato tubers of several varieties frequently crack at harvest to a very serious extent when grown in the northern Great Plains region as a late-summer and autumn crop. Tubers of the Triumph variety crack more readily than those of any other variety grown in that region. Sometimes tubers crack while they are still in the soil and attached to the plants, but most of the cracking occurs during the harvesting of the crop. The pictures shown in figures 1 and 2 illustrate the extent and severity sometimes attained by these cracks.

Apparently cracking occurs when tubers develop very high turgor pressure. Such pressure may be generated when the amount of water lost by transpiration from plants well supplied with moisture is reduced more or less rapidly. Reduction in transpiration may be due to such factors as a reduction in temperature, increase in humidity, a reduction in air movement, or some sudden reduction in area of green-leaves without damage to roots (as by hail or disease). Sometimes this pressure is great enough to cause tubers to crack while still in the soil. Recently developed cracks of great severity were observed in October, 1940, when Triumph potatoes were dug from partly green plants during a cold rainy morning which had been preceded by a rainy night following a bright sunny day as shown in figure 1. Such cracks are

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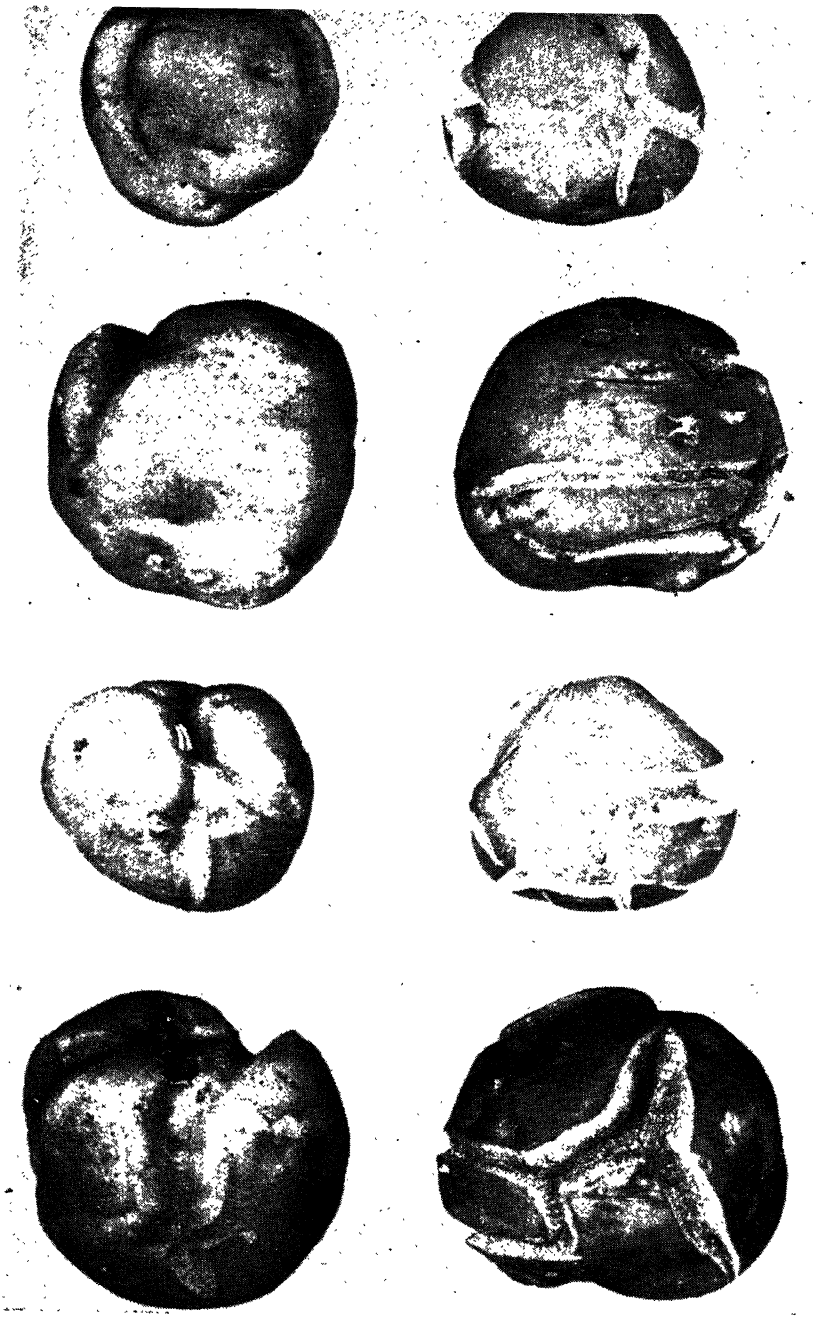

FIG. 1.—"Growth cracks" that occurred during one cool damp night following a bright early October day. Both sides of each tuber are shown.

commonly referred to as "growth cracks" although they may actually be caused only by rapid swelling following very rapid absorption of a large amount of water.

Upon being removed from the soil, tubers under high turgor tension crack very easily if subjected to relatively mild physical shocks. Cracks developing during the harvesting process—especially those developing before picking—are commonly referred to by farmers as "air checks," inferring thereby that the tubers crack because of exposure

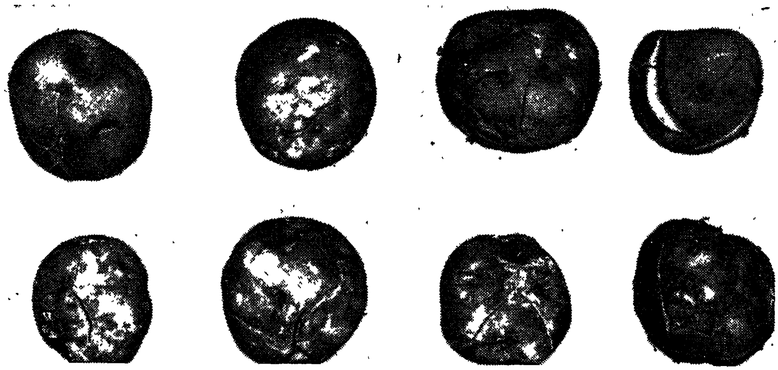

FIG. 2.—Typical cracks occurring in Triumph potatoes at harvest time.

to the air. That may be the case but numerous observations and tests under a great variety of air conditions lead to the conclusion that cracking due to exposure to the air is not the rule.[1] Almost invariably the fresh cracks seen at harvest time are found to have originated with some skin abrasion or mechanical shock. The severity, that is number, length and depth, of cracks appears to be associated more closely with turgidity of the tuber than with the severity of the shock (Fig. 2).

The average percentage of cut and cracked potatoes (of which most were cracked) varied from 9.5 to 31.1 per cent of the crop harvested by all Nebraska certified seed potato growers in the years 1928 to 1935 (28, 32). During these years individual growers succeeded in harvesting their crops with less than 5 per cent mechanical damage, whereas others have damaged over 75 per cent of the tubers. In years, such as in 1940, it is extremely difficult to handle the crop without doing serious damage to the tubers.

[1]Shortly after this manuscript was submitted, the author received a letter from A. Clem Foster, Marketing officer for the Potato Marketing Board of Tasmania, Australia, in which he reported that their variety "Brownell" is very subject to cracking and that frequently the tubers are heard to crack when they are held on the wharves in bags.

Review of Literature

In initial studies of this problem, Werner reported that Triumph tubers subjected to a standard test cracked nine times more severely than Irish Cobblers (28). Under conditions that resulted in high turgidity in Maine potatoes, Bonde (5) reported that Green Mountain potatoes cracked severely but Irish Cobblers not at all.

Werner (28) reported that cracking increased as planting was delayed from May 20 to June 27. He found that cracking decreased from 24 per cent to 5 per cent as harvesting was delayed for a period of 8 days in early October. He also found that cracking increased during cool damp weather. Tubers from plants with many green leaves cracked much less readily than those on plants that had a decreased leaf area due to partial maturity, early blight or frost damage. When tops were cut off at the surface of the soil from four or seven weeks before harvest, tubers cracked less at harvest time than those from undamaged vines, but when cut at a height of six inches there was no reduction in cracking (29). During the first few days after the vines were cut at the surface of the soil there was an increase in cracking but six days later it was less than with tubers from the uncut vines (28).

In England it was found that when soil was damp, tubers cracked more severely for several days after the vines had been killed with a sulfuric acid spray than where they had not been killed (12).

It is desirable to inquire into the probable causes of this increased tuber turgidity. The question might be asked—is this increased turgor which is associated with tuber cracking propensity a result of unusually rapid tuber growth or is it merely due to increased hydration of tuber tissues?

MacMillan (14) reported considerable variation in the rate of growth of potato tubers throughout a 24-hour period and he concluded that this was due to variations in above-ground conditions. Apple fruits have been found to enlarge most rapidly during periods of low evaporation. Air movement and high temperatures appeared to be factors of most importance in retarding fruit growth (10). The growth of pear fruits was reduced during periods of high transpiration even when soil moisture was abundantly available (1).

Reduction in day length and temperature, such as occurs in September, has been found to cause a cessation in growth of vines and a rapid increase in tuber production with potatoes (7, 27, 31). This rapid growth in September and October and several biochemical aspects of tuber growth at that time may contribute to increased pressure within

tubers. Several investigations have shown that potassium is absorbed by tubers in increasing quantities as they approach maturity whereas the amount of calcium absorbed increases but very little as tubers develop (3, 6). Consequently the ratio of potassium to calcium increases steadily in growing tubers. With an increase in potassium content, an increase in osmotic and turgor pressure is to be expected. It has been shown that the permeability and water-absorbing capacity of disks of potato tubers was increased by potassium and decreased by calcium (3, 17, 18, 23).

Wright (35) and other workers have found that as the storage temperature decreases below 50°—especially from 40° to 36° F.—sugar content of potato tubers increased rapidly. Werner (30) found that the percentage of sucrose was higher in Triumph tubers that were produced under conditions very favorable for tuberization (short cool days) than during days less favorable for rapid tuber development (long warm days). Under the latter conditions the sucrose content was greatest in tubers produced by plants growing with a reduced nitrogen supply. On the high plains field conditions in late September are very favorable for a great increase in sugar content of tubers. It is recognized that tubers dug in cool weather from immature vines are sweeter than those maturing earlier in the season or even the same tubers after several weeks in storage at 40-50° F. The sweet taste of cooked potatoes and dark brown color of potato chips are very evident criteria of this sweet condition (24). In view of the well known fact that osmotic (or turgor) pressure increases as the concentration of a sugar solution increases, it seems logical to conclude that the increase in sugar content can well account for some increase in turgor pressure of tubers.

Research with fruit crops indicates that factors reducing transpiration and not increases in soil moisture, were responsible for cracking of cherries, figs, and apples (20, 21). Verner reported (25, 26) that Stayman Winesap apples cracked after a six-hour period of greatly depressed transpiration. During such periods fruits swelled greatly because of the greater amounts of water available through the stems plus the direct absorption of some water through the skin of the fruit. Cracking seemed more pronounced when foliage was sparse than when it was dense and when fruits were growing rapidly rather than when fruit growth was slow.

The authors have observed a tremendous increase in cracking of tomato fruits during damp cloudy periods but no especially noticeable increase in cracking following furrow or overhead irrigation.

There is evidence at hand to indicate that cracking of tubers can occur not only as a result of a mechanical shock and rapid reduction in water loss from tops of plants whose tubers are swelling rapidly, but may be the consequence of direct absorption of water by the tubers through minor injuries or lesions in the skin or through the skin. From England it is reported that sound tubers cracked very severely following a few days of rain, which soaked through the straw covering of a damp (pit) whereas no cracking occurred where the tubers remained dry (12).

In October, 1940, the authors observed extraordinarily severe cracking of a number of seedling tubers that had been left on the surface of the soil overnight when a slow drizzly rain occurred. In many cases these tubers were found to have had minor abrasions where absorption began but in others there was no evidence of any break in the skin.

Edgar has reported that injury to tubers was reduced if the storage temperature were raised prior to midwinter sorting so as to bring about a reduction in tuber turgor (3). This has also been the experience of potato growers sorting potatoes in cool damp western Nebraska cellars.

When freshly dug potatoes were exposed to the air, the cracking susceptibility following a shock decreased in proportion to the length of time tubers were exposed (28). With a lot of Triumph tubers that were cracking very readily when pricked with a pin, MacMillan (15) reported that the cracking ceased entirely when the tubers lost about 6 per cent of their original weight through exposure to air.

Potato growers have repeatedly inquired concerning the possibility of destroying vines with a flame or with a vine-killing spray as a means of eliminating some of the difficulties in handling vines and cracking tubers at harvest time. In preliminary tests we found that an excessively large amount of fuel and time was required to destroy green potato vines with a flame and that method appears very impractical with present day facilities. Spraying with sulfuric acid has been found to be very effective in England (4) not only for killing green vines but also for killing late blight (*Phytophthora infestans*) spores and thereby decreasing tuber rot losses in storage. The work of Jones and Moore (12) demonstrated that when conditions were favorable for the cracking of tubers—killing vines with sulfuric acid increased the amount of cracking for a period of several days but after a week there was little or no effect. They did not determine the effect of such vine killing to tuber cracking if tubers were harvested more than a week after

spraying with acid. From a practical standpoint sulfuric acid spraying has many disadvantages. It kills only where the spray actually hits the leaf and anything approaching complete killing is impossible when vines are very large. Because of its corrosive action operators must wear rubber clothing, and spraying outfits must be specially equipped to handle acid. Some recent tests in California (33) have demonstrated the effectiveness of sodium dinitro-ortho-cresylate as a weed killing spray. This material has also been used as a herbicide, fungicide and ovicide for killing moss, fungi and insect eggs on trunks and branches of fruit trees in Europe (19). It has several advantages over acid sprays; being non-corrosive, it can be used in any spray outfit, operators need not use rubber clothing, and a complete cover is not required since one drop is capable of killing a considerable area of tissue without being spread over the entire area; however, being a dye it stains clothing.

During the summer of 1940 the senior author observed a great reduction in the amount of feathering with Irish Cobblers dug from immature vines by McConnell Brothers at Gibbon, Nebraska, when the potato roots had been cut with a modified digger blade 8 to 12 hours in advance of digging. So far as we know this method had not been tested as a means of reducing cracking of potatoes at harvest time but appeared more promising than vine killing by spraying.

Objectives and Experimental Procedure

As more or less cracking at harvest time appears to be inevitable under some growing conditions—especially with Triumph potatoes harvested in the early autumn, it was necessary to secure more information regarding the relation of weather conditions to cracking and the possibility of managing fields in order to reduce the cracking susceptibility of the tubers. Root-cutting appeared to be a more promising method than vine destruction by spraying. However, because of the advantages in harvesting if vines have been destroyed and also because of the possibility that herbicide sprays might also kill spores of early blight* and thus prevent some storage rot losses, it seemed desirable to give vine-killing sprays another trial.

The characteristics of the fields, condition of the plants and description of the treatments and special apparatus used are described in connection with each experiment.

In all experiments the cracking susceptibility was determined by

*(*Alternaria solani* (E & M) Jones and Grout.)

dropping each of 50 typical tubers of each treatment a distance of 25 centimeters (about 10 inches) on to a clean brick as rapidly as individual hills were dug by hand. Such tubers were then laid out and as soon as convenient each tuber was weighed and the length of each crack was recorded. Objection might be raised to not measuring cracks at once, but tests showed that these cracks do not become longer during exposure to the air. The data are reported as percentage of tubers cracking and as total length of cracks in centimeters for each 50 tubers tested. The latter basis seemed to provide the best index of the cracking suceptibility of tubers of a treatment and consequently it is used throughout most of the discussion.

A few simple tests were conducted to determine whether some of the increased tuber-cracking susceptibility might be due to the absorption of water through the skins of potatoes.

Root Cutting and Vine Killing Experiment: Early Test

Charles Barbour of Scottsbluff irrigated a portion of a field of late planted (June 27) Triumph potatoes from a well on September 14, so as to induce maximum turgidity in the tubers. The vines were in relatively good condition when the experiment was started, except for a light scattering of spots of early blight on most of the leaves. Damage from early blight became very evident about September 20 and increased rapidly so that by September 23 most of the leaves were dead but most stems of check rows remained green until approximately October 3.

Starting at 8 A.M. on September 18, before applying any experimental treatments, 200 tubers dug by hand from hills scattered over the field were tested, regarding their cracking susceptibility. The experimental treatments were applied between 9:30 A.M. and 11 A.M. The roots were cut under four rows of plants with a potato digger blade modified somewhat as shown in figure 3. Plants in four rows were sprayed with 7½ per cent sulfuric acid (percentage of crude sulfuric acid by volume) with a knapsack sprayer, going over the rows a second time an hour after the first application. Four additional rows were sprayed with 3 per cent Elgetol Extra (21 per cent dinitro-ortho-cresylate plus 43 per cent of a penetrant) using a power sprayer, three nozzles per row, 300 lbs. pressure, 125 gals. per acre, and four rows were left unsprayed as a check. The cool and cloudy weather that ensued until October 9 caused tubers to be unusually susceptible to cracking and consequently provided an excellent opportunity for a test of these methods.

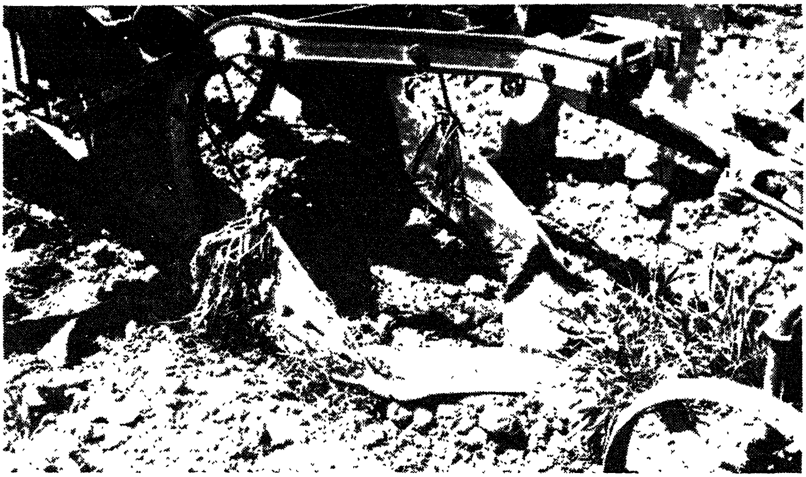

FIG. 3.—A potato digger altered for root cutting. Note that belt has been removed and rear portion of blade is cut out, and blade is flattened somewhat so that the ground will be disturbed less than with unmodified digger blade.

Starting at 1:00 P.M. 50 tubers were harvested and tested from each treatment. A similar series of tests was conducted starting in the morning and afternoon of the next two days and thereafter at intervals until October 9. The results of these tests are shown graphically in figure 4 because of the very close similarity of results from the acid and Elgetol-sprayed plots—the results from those two plots were averaged and reported as such in the graphs.

The vines of the root-cut rows dropped rapidly the first afternoon and were practicaly dead by about September 24. In the rows sprayed with sulfuric acid the leaf or stem tissue was dead within a few hours but areas not hit with the spray remained green for a long time and stems remained green almost as long as with check plants. The plants in the Elgetol-sprayed rows did not show much evidence of damage during the first day but serious damage was apparent after 30 hours and the plants (including stems) were completely dead at the end of 48 hours.

Between 8 A.M. and 1 P.M. of the first day there was a decrease in cracking with all treatments, but the root cutting caused a decrease in cracking beyond that occurring in the check as shown in figure 4. By 4 P. M. the cracking again increased in all lots due, undoubtedly, to the cool cloudy weather which began at noon, the temperature continuing to decrease all afternoon. On the morning of September 19, the check tubers were cracking as severely as ever, but those in the sprayed

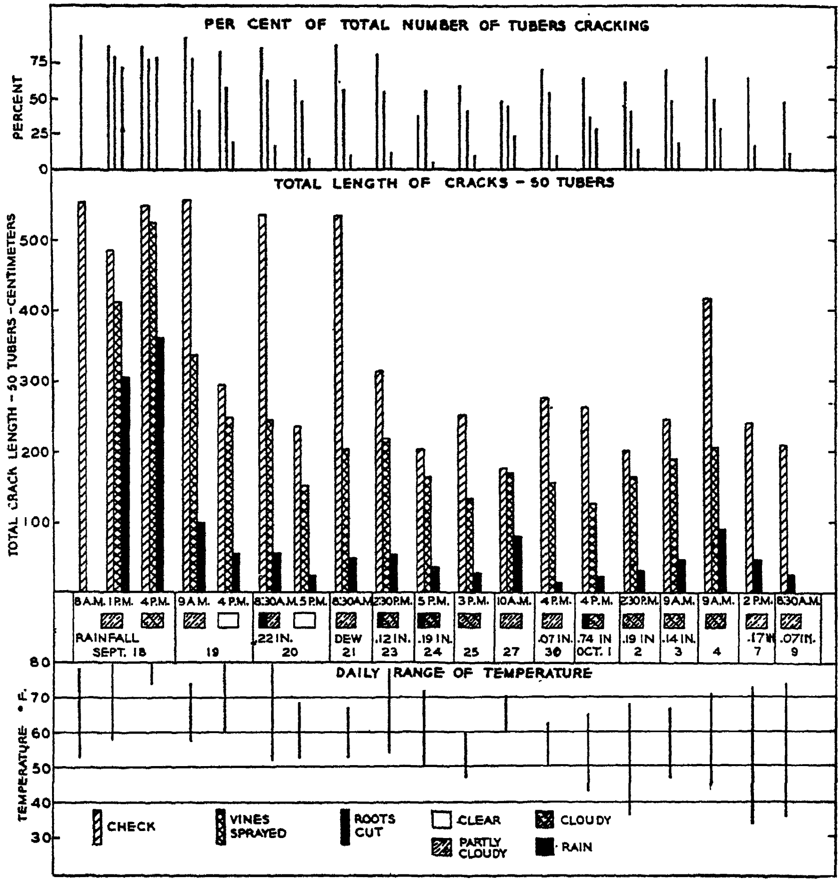

FIG. 4.—Cracking occurring in samples of 50 tubers from each of September 18 experimental treatments when subjected at periods designated to standard test (dropping tuber 25 cm.—10 inches on to a brick) expressed as percentage of tubers cracking or total length of cracks. Temperature range and weather conditions during interval preceding each test are described graphically.

plots were cracking much less and with root cutting treatments the cracking was less than 20 per cent of that of the check tubers. By the close of a clear warm afternoon cracking of check tubers was reduced about 50 per cent and there was a still further reduction in cracking in root-cut plots. During the next night .22 inches of rain fell and cracking of check tubers was again at the original level on the 20th of September, but the tubers of sprayed and root-cut plots did not show any more cracking than was prevalent the previous afternoon. Follow-

ing the clear afternoon of the 20th of September, cracking again decreased greatly in the check tubers only to return to the original level of severity during the damp cloudy morning of the 21st of September. From the 23d of September to the 2d of October, the check vines lost foliage because of blight, and they also were maturing rapidly. Samples dug during the afternoons of these days continued to crack about the same as in the afternoons of the 19th or 20th of September. During this time tubers of the root-cut plots scarcely cracked at all. Following a prolonged damp period from the 30th of September to the 3d of October, a rainfall of 1.14 inches occurred. As the vines were quite decrepit at this time practically all of this water soaked into the soil filling the top 6 inches or more to field capacity. Consequently on the 7th of October, tubers in check plots again cracked very extensively and cracking increased in the treated plots. Cracking again decreased during the relatively clear weather of the 7th of October. On the 9th of October, when the field of potatoes was harvested and the experiment terminated the check tubers were still cracking about 40 per cent as much as they did on the 18th of September.

This experiment demonstrates quite clearly that when Triumph tubers in a field are cracking badly, the cracking is most severe in cold or damp mornings decreasing as the day warms up, or the water loss from leaves is increased by lowering the humidity or decreasing of wind velocity. It also shows rather clearly that on plants with very decrepit tops, cracking may again become more prevalent during cool or cloudy weather if there is an increase in soil moisture. Killing vines by spraying may be a fairly effective, but not a rapid method of reducing cracking damage. In this experiment with minimum temperatures above 50° F. during the first few days after root cutting, it was a very effective method of bringing about a prompt reduction and almost complete cessation of tuber cracking.

Late Root Cutting Test

The rainy, cloudy, and increasing cooler weather during late September and early October (Figs. 4 and 6) was responsible for conditions very favorable for tuber cracking when the potato harvesting season of 1940 got under way. Farmers that had attempted root cutting reported that they were not getting any benefits but, as is quite typical of practical operators, they had no controls, the roots of all of the vines in a field having been cut. In testing the cracking susceptibility of several varieties from relatively green plants of a June 20 planting on the Scotts-

bluff Experiment Farm we discovered that cracking was occurring to a more serious extent during these first few days of October than in the earlier-planted and more mature field used for the other experiment. Consequently we cut the roots under several rows of potatoes at 1 P.M. on October 4. At this time a specially built cutting blade attached to a tractor was used (Fig. 5). This device cut the roots without appre-

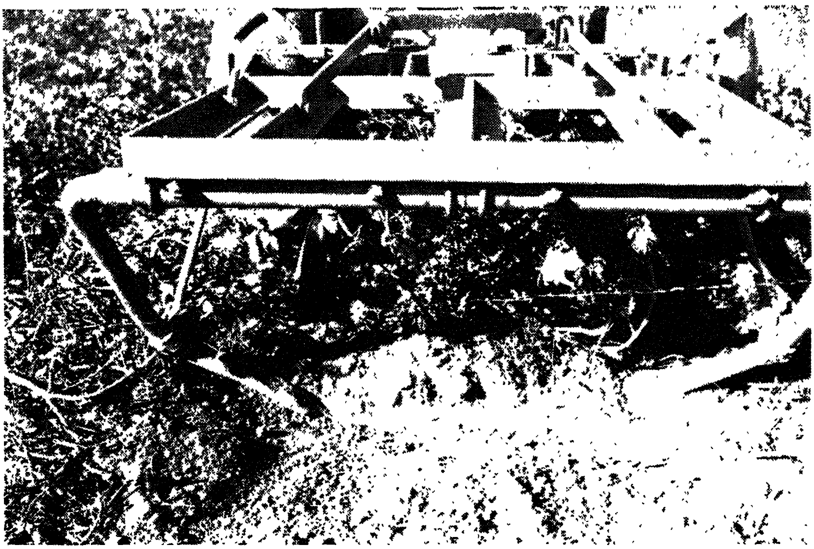

FIG. 5.—Specially built cutting blade mounted on the hydraulic lift attachment of a tractor. This equipment was used in the later root cutting tests.

ciably disturbing the soil mass. The revolving disk vine cutters prevented the pulling or dragging of any vines. The top foot of soil contained a liberal supply of moisture as a result of rains on October 1st, 2d and 3d as shown in figure 4.

The customary afternoon reduction in cracking was observed when tubers from check plants were tested at 4 P.M. 3 hours after the roots were cut. Tubers of root-cut plants cracked slightly less than the check plat tubers as is revealed in figure 6. When daily minimum temperatures dropped below 40° F. and maximum generally below 70° F. cracking increased, continuing to be relatively severe for several days (October 6 to 11). Following the clear warm weather of October 11th, cracking decreased considerably. On all days the tubers in the root plots cracked less than the checks—but the differences were much less than in the earlier experiment.

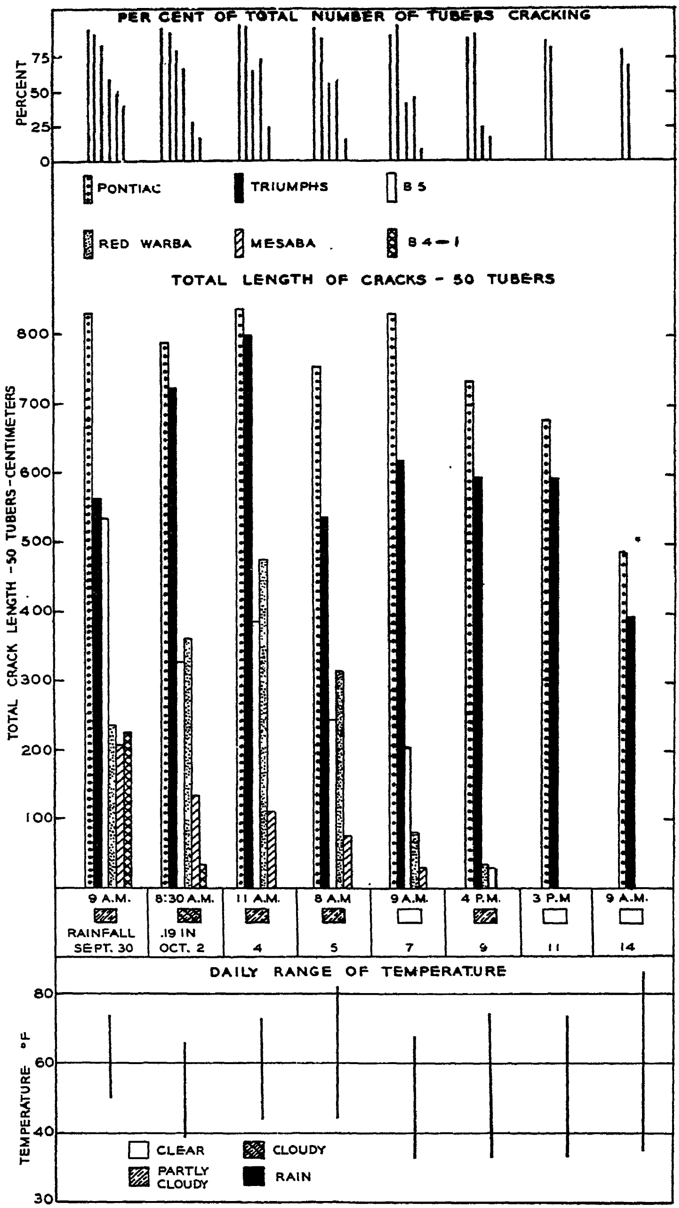

FIG. 6.—Cracking occurring in samples of 50 tubers from root cut and control plants tested with standard test at intervals after root cutting on October 4 with machine illustrated in figure 5. Results expressed as percentage of tubers cracking or total length of cracks. Temperature range and weather conditions during interval preceding each test are described graphically.

These results indicate that further experimentation is necessary in order to increase the certainty of the method under a variety of conditions. As pointed out, the device used in this experiment cut the roots without disturbing the soil appreciably. The soil mass above the cut contained a large quantity of undisturbed roots that were probably able to supply the plants with an abundance of moisture from the very moist soil. Under such conditions when moisture is available close to the plants an extensive root system is not necessary, Davis (8) having demonstrated that when water is readily available close to plants they do not draw on moisture at a distance even though roots are there. Consequently, there was only a slight moisture deficit, if any, in the tops and the turgidity of tubers was not greatly decreased. In fact the tuber turgidity apparently increased during a period of continually cool weather. Possibly the slightly sloping and less smooth working digger blade used in the first experiment might have had some advantages over the smooth working blade used in this experiment. The more extensive disturbance of the soil may have torn many small roots and may have opened the soil more to drying atmospheric influences in a way that was beneficial instead of detrimental. If that is the case, then cutting edges used should be adjustable for the various soil and atmospheric conditions. Such a loosening of the soil may be undesirable if frost is imminent and with early potatoes it may be undesirable because it may bring about an excessive loss of water from the tubers causing them to become "rubbery". Where the soil was loosened in this manner by the root cutting process some growers encountered difficulty in getting the soil and potatoes to move back over the blade on to the digger belt.

Direct Water Absorption by Tubers and Increase in Tuber Cracking

The increase of cracking of tubers under dead vines when soils become wet, due to late rain raised the question as to whether the cracking were due to moisture absorbed through the skin of the potato, or through the partially dead root and underground stem system. Kramer (13), has recently shown that with identical suction, plants with dead roots are capable of absorbing water at a more rapid rate than those with living roots, because the living cells offer more resistance to water movement, especially at temperatures below 45° F. The live tuber tissue might offer such resistance to water movement out of the xylem tubes into the parenchyma of the tuber. On the other hand

the osmotic pressure or colloidal imhibitional forces of the tuber might be able to draw considerable water through the potato skin—which on a growing tuber, while under ground in damp cool soil, is probably quite permeable. Root pressure might be a contributing factor in case roots are still intact, however the work of Kramer (13) showed root pressure to be a relatively minor force in connection with the upward movement of water in tomatoes and sunflowers.

Three methods of keeping potatoes damp after harvesting were used in order to determine the change in susceptibility to cracking. This susceptibility decreased slightly when they were kept damp by intermittent sprinkling as shown in table 1. Cracking increased 13 to 27

TABLE 1.—*Total length in centimeters of cracks in 25 Triumph tubers tested at digging time and another set of 25 tubers harvested at the same time but placed under various conditions designed to keep potatoes damp for 2 hours before testing for cracking*

Time when dug A. M.	Crack Length Check Tested When Dug	Treatment for 2 Hours after Digging before Testing: In Shade Sprinkled	In Saturated Soil	In* Water	Per cent Increase of Decrease in Cracking Following Treatment
	cms.	cms.	cms.	cms.	
8	145	132			—9.0
10	151	140			—7.4
7:30	190.5		215.8		+13.3
9:30	175.4		222.6		+27.0
7	127.6			209	+63.7
8:30	128.7			222	+72.4
10	101.3			154	+52.0

*These tubers absorbed water to the extent of about 15 per cent of the weight when harvested.

per cent when freshly dug tubers were placed in soil that was saturated immediately. When freshly harvested potatoes were soaked in water for two hours cracking increased 52 to 72 per cent. Apparently much ot the cracking of these tubers on old vines resulted from the direct absorption of moisture through the skin of the potato, thus accounting for the increase in cracking that occurred after October 6th. Root cutting or vine killing was of little or no assistance in alleviating this situation. However, disturbing the soil in order to bring about greater

aeration, as by a sloping digger blade used in root cutting, might have accomplished beneficial results.

Difference in Variety Susceptibility to Cracking

The rainfall in late September stimulated very rapid tuber growth in practically all varieties that were being grown in late-planted trial plots at the Scottsbluff Experimental Farm. The cracking susceptibility of eight of these varieties was tested during a 15-day period. At the beginning of the test on September 30 only a few blight spots were found on Katahdin and Chippewa plants, the line B5 (Minnesota 1.33-1-34) had a few more blight spots. Losses of leaf area amounted to approximately 50 per cent with Triumph 4 (second early strain) and Irish Cobbler; 5 per cent with Pontiac; 10 per cent with B4-1 (Minnesota 29.32-1-34); and 80 per cent with Mesaba. As the season advanced blight became more severe with all varieties so that damage by October 7 amounted to approximately 50 per cent with the late varieties and 90 to 100 per cent with the early varieties. The cracking data for most of the varieties are shown in figure 7.

Very few cracks were produced in Irish Cobbler, Chippewa or Katahdin tubers and for that reason no attempt is made to plot data for those varieties. The Pontiac tubers cracked more than those of the Triumph. However, some of the cracking in Pontiac may have been caused by the spindle-tuber disease which was present in the lot, even though obviously infected tubers were not used in the tests. We have found that spindle-tubers from partially dead plants crack more readily than do normal tubers from plants that have leaves in better condition.

The B5 and Red Warba, both derivatives from the Triumph, cracked less than Pontiac and Triumph and completely ceased to crack when the latter varieties were still cracking at a very serious rate. The Mesaba and B4-1 cracked much less than the other varieties and also suffered very little cracking at a time when the Triumph and Pontiac were still cracking extensively.

As in the second experiment, tuber-cracking decreased rapidly following the clear warm weather of October 11.

We can only suggest possible reasons why Triumph tubers crack so much more readily than any of the other commonly grown varieties. Wright (35) found that the sugar content of Triumph potatoes—especially sucrose—increased much more rapidly at low temperatures

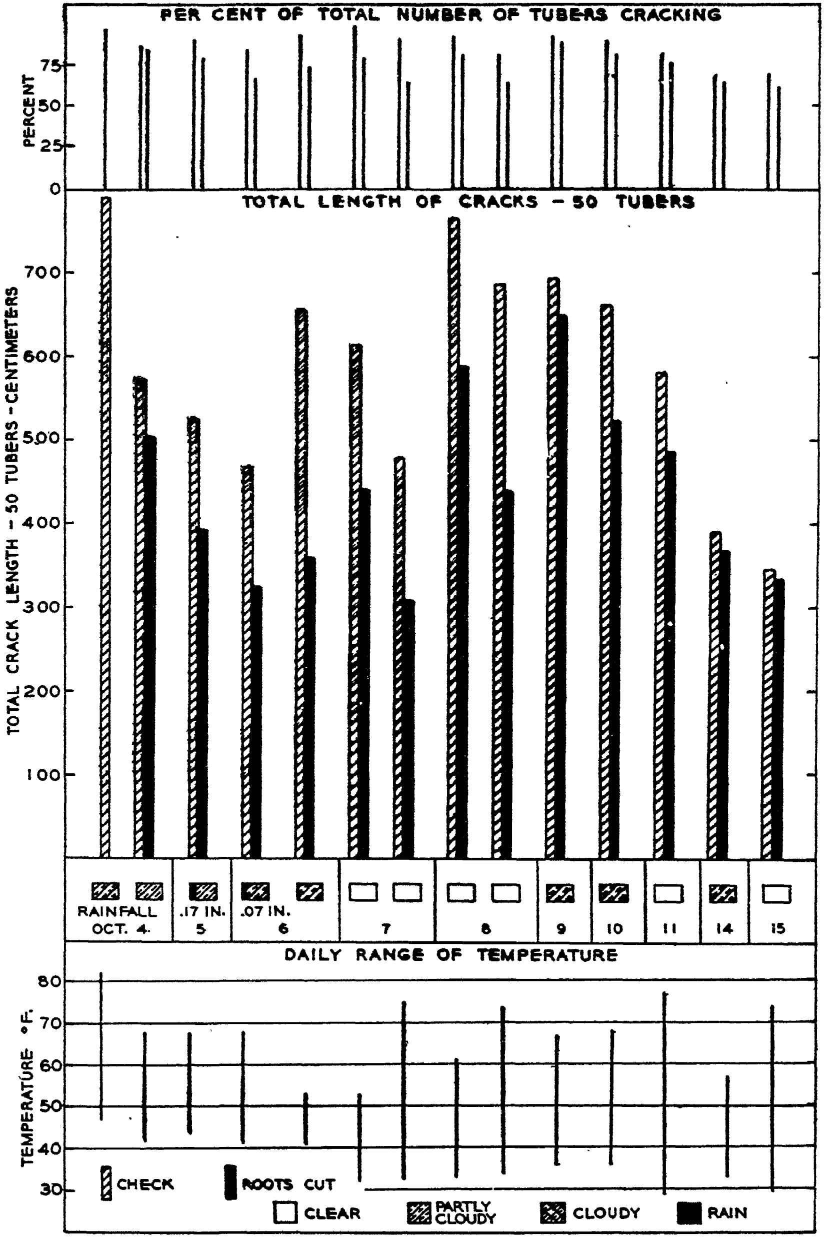

FIG. 7.—Cracking occurring at various test dates with 50 tuber samples of potatoes of several varieties. Results expressed as percentage of tubers cracking or total length of cracks. Temperature range and weather conditions during interval preceding each test are described graphically.

(40 to 36° F.) than with Irish Cobbler. Such differences might bring about a difference in osmotic or turgor pressure[2].

According to numerous determinations of the rate of water loss through leaves as determined by the cobalt chloride paper method, during several days in the summer of 1940, transpiration was consistently less rapid from Triumph than from Irish Cobbler leaves. When conditions causing high transpiration increased rapidly early in the day the Irish Cobbler leaves continued to transpire rapidly but the water loss from Triumph leaves diminished early and continued at a reduced rate until late afternoon or until the conditions moderated. This might have been caused by a decreased amount of water available from the Triumph roots but the end result would be to leave more moisture in the soil. According to unpublished data, from four date-of-harvesting experiments, Triumph tubers consistently had a higher percentage of moisture than Irish Cobbler tubers of the same size, harvested on the same date at various intervals throughout the tuber-production season.

It is of course possible that structural differences may play a part. The internal structure of the Irish Cobbler tubers with a large solid central pith area is very different from that of the Triumph which has pith regions extending as narrow arms into zones of perimedullary tissue resulting in a very small central pith area (2). When subjected to conditions that rapidly accelerate growth or tuber hydration while still attached to a living plant, tubers of the type of Irish Cobbler with a large central pith area develop hollow heart, the pith not being able to increase as rapidly as peripheral portions. Under such conditions the Triumph tubers appear to develop pressures in the central portions which are too great for the peripheral tissues. Miller (16) suggests that swelling of tissues is dependent not only on permeability of protoplasmic membrane to water, but on elasticity of cell walls. That suggests the possibility of differences in the elasticity of the cell walls of varieties or of certain regions of different varieties.

Summary

Cracking of potatoes at harvest time constitutes the most serious grade defect generally encountered by growers of late crop Triumph

[2]Thornton and Denny report much more rapid accumulation of reducing sugar in potatoes stored at 5°C. immediately after harvest than when stored at that temperature several weeks later. The variety Green Mountain (which according to Bonde (5) cracked more in Maine than other varieties) accumulated reducing sugar more rapidly in early cold storage than did Russet Rural tubers. (Thornton, Norwood C. & F. E. Denny. 1941). Rate of development of reducing sugar in cold stored potato tubers as related to time of harvest at which storage was started. Am. Soc. Hort. Sci. 38:266.

potatoes in the northern high plains. The probable causes of this difficulty are considered.

It appears that tubers crack because of a great increase in turgidity, which apparently results when transpiration is greatly reduced while the roots are well supplied with moisture or when, following a dry period, the soil moisture is greatly increased while the transpiration rate is very slow. Under such conditions cracking of Triumph tubers increases greatly.

In fields irrigated in mid-September, 1940, killing sprays were applied and roots were cut. At intervals thereafter samples of tubers were subjected to standard tests to determine the susceptibility to cracking.

Root cutting very effectively reduced the amount of cracking. The effect of killing vines was slower and less extensive.

When soils were wet and vines were senile, root cutting was less effective, high turgidity of tubers apparently being maintained by direct absorption of water through the skin of the tubers.

Because of the large amount of feeding roots in the soil above the root cutting zone and the probable direct absorption of moisture by tubers from moist soil it appears that some loosening of the soil to promote drying out is as essential as root cutting when several inches of surface soil remain moist.

The amount of cracking fluctuated from day to day and throughout any day—increasing over night or any time during cold or cloudy periods and decreasing during bright or windy days.

Tubers of Triumph and Pontiac cracked most readily, those of two new seedlings were less susceptible, Mesaba and Warba were still less susceptible, and very little or no cracking could be induced in Irish Cobbler, Chippewa, and Katahdin.

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VARIETAL SUSCEPTIBILITY OF POTATOES TO FUSARIUM WILT[1]

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During recent years a number of new potato varieties have been distributed to growers by the United States Department of Agriculture or by State Experiment Stations. These varieties have been described in various publications and a good comparison of their characters has been presented by Stevenson.[2] Although their reaction to certain diseases has been tested and reported upon by various workers, practically no information has been presented on their relative susceptibility to fusarium wilt.

A number of these recently released varieties, as well as several promising hybrids, have been included in the fusarium-wilt tests that are being conducted as part of the potato breeding program in Nebraska. It was thought that the results to date would be of interest to those engaged in breeding for disease resistance, particularly in those sections of the country where this disease is a problem.

The tests have been conducted under irrigation at the Scotts Bluff Substation in western Nebraska. The field was planted with severely infected seed tubers in 1936 and has been planted continuously to potatoes since that time. In 1939 and 1940 inoculum of *Fusarium solani* var. *eumartii* in sterilized soil was added at the rate of one-half pound per foot of row just before planting.

Five to ten replications of 5-hill units were used for each variety and Irish Cobbler and Bliss Triumph check units were inserted alternately every fifth unit. Records were made of the occurrence of wilt in the field, but the emphasis has been placed on stem-end rot and vascular discoloration of the tuber, as this is the phase of the disease that causes the greatest loss in Nebraska. Stem rot and wilt due to *F. solani* and wilt due to *F. oxysporum* occurred in the field but neither of these diseases produces stem-end rot of the tubers and although *F. oxysporum* produces vascular discoloration in the tubers, it does not produce the severe types characteristic of infection with *F. solani* var. *eumartii.* More than 90 per cent of the foliage symptoms and

[1]Published with the approval of the Director as Paper No. 282 Journal Series, Nebraska Agricultural Experiment Station.

nearly all of the tuber symptoms were of the *F. solani* var. *eumartii* type. In recording the results, only those tubers were listed as positive which showed internal discoloration, the removal of which would involve more than 5 per cent of the tuber by weight, or tubers with stem-end rot. These tubers usually showed a wide band of water-soaked, brownish tissue extending far enough into the tuber to be classified as "damage" and many of them would fall in the "serious damage" class of grade defects. Many additional tubers showed slight vascular discoloration in amounts proportionate to the severe types and these are listed as questionable infection in table 1.

Even though these tests have extended over a four-year period, some varieties were not included the first two years and therefore the data are presented for 1939 and 1940 only, when all lines were being tested. The results of the first two years' trials were essentially the same as shown for the last two years.

The amount of infection was much greater in 1940 than in 1939 but, with the exception of Houma, the varieties can be grouped similarly in both years. Houma has been included in the tests for four years but the results were just as inconsistent during the first two years.

The varieties Pontiac, Katahdin, Golden, and Sebago along with the two hybrids have had consistently low percentages of infection and can be considered the least susceptible of any of the new varieties tested. The varieties White Rose, Earlaine, and Chippewa were much more susceptible, whereas the Mesaba and the Warba were even more susceptible than the Cobbler and Triumph checks. The use of any of these very susceptible varieties in sections where fusarium wilt is prevalent would be attended by the same difficulties that confront the growers of Cobblers and Triumphs. The Warba in particular should be avoided wherever this disease is common.

Fusarium-wilt tests on four German varieties that are not shown in the table, were also conducted. These varieties were Erstling, Richter's Jubel, Hindenburg, and Arnica. Erstling was just as susceptible as the Cobbler and Triumph checks, although Arnica was much less susceptible, having about the same amount of infection as the least susceptible varieties in table 1. Hindenburg showed less infection than any of the American varieties, only a low percenetage of tubers being graded as questionable, whereas none was graded as positively infected. In three years' field tests of the Jubel variety no infected or questionable plants or tubers were found, while in sterilized and heavily inoculated soil in the greenhouse only a mild type of wilt

TABLE I.—*Results of two years' tests of varietal susceptibility to fusarium wilt, based on tuber symptoms*[1]

1939					1940				
Variety	Tubers				Variety	Tubers			
	Total Number	Healthy	Questionable Infection	Infected		Total Number	Healthy	Questionable Infection	Infected
	No.	Per Cent	Per Cent	Per Cent		No.	Per Cent	Per Cent	Per Cent
Houma	110	98.2	1.8	0.0	B4-1[3]	204	90.1	5.9	4.0
Pontiac	173	97.7	1.7	0.6	Golden	256	88.6	5.9	5.5
B5[2]	139	95.6	2.9	1.5	Katahdin	213	82.2	10.8	7.0
Katahdin	185	94.1	3.7	2.2	Sebago	123	82.1	10.6	7.3
Golden	227	93.9	3.5	2.6	B5[2]	168	81.6	12.5	6.0
Sebago	123	93.5	5.7	0.8	Pontiac	213	77.4	15.5	7.0
B4-1[3]	103	93.2	5.8	0.9	White Rose	232	75.9	9.5	14.7
White Rose	109	92.7	2.7	4.5	Earlaine	213	73.7	18.3	7.9
Earlaine	128	87.5	9.4	3.1	Chippewa	311	68.1	15.8	16.1
Chippewa	152	85.5	9.9	4.6	Bliss Triumph	728	68.1	10.9	21.0
Bliss Triumph	1648	82.0	13.3	4.7	Irish Cobbler	991	65.9	13.3	19.7
Irish Cobbler	1312	81.1	13.9	5.0	Mesaba	242	63.6	19.4	17.0
Mesaba	21	76.2	23.9	0.0	Houma	64	51.6	12.5	35.9
Warba	185	71.9	21.6	6.5	Warba	201	51.2	16.9	31.8

[1]Tubers listed as infected had internal discoloration involving more than 5 per cent of the tuber or stem-end rot.
[2]Minn. 1.33-1-34.
[3]Minn. 29.32-1-34.

without tuber infection was produced. Although fewer plants of this variety have been tested, it has consistenly shown greater resistance to fusarium wilt in both field and greenhouse tests than has any other variety.

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REPORT OF COMMITTEE ON NOMENCLATURE

The study of stocks of potatoes listed by seed firms, which has been conducted by the Nomenclature Committee of this Association for several years, was continued by the chairman during the past season. The following three varieties obtained from such sources were found to be incorrectly named:

Irish Cobbler, listed as Extra Early Prize.

Spaulding Rose, listed as Bovee.

American Giant (White Rose), listed as American Wonder.

During the past few years several varieties belonging in the Rural Group have appeared in New York State, regarding which but little information has been available. A discussion of these varieties by Dr. E. V. Hardenburg is given below under the heading "Status of the Rural Type Potato in New York."

"Between 1882 and 1896, E. S. Carman of River Edge, New Jersey, placed on the market such well known potato varieties as Rural New Yorker No. 2, Carman No. 3, and Sir Walter Raleigh. Apparently this represents the origin and introduction of the Rural type of potato in this country. These varieties originated from natural seedballs as Mr. Carman was unable to find any functional pollen from the parent plants. Parenthetically, this is probably true today, as no one has recently reported finding any but parthenocarpic fruits on varieties of the Rural type. As early as 1905, according to a report by East,* over 80 per cent of the commercial crop grown in Minnesota and Wisconsin was of this type. N. A. Baker of Fairport, New York, claims to have stock of the original Carman No. 3 at the present time.

"Since these original Rural varieties were introduced, many varieties of this same group or type have been put into production. Among them may be listed the following: Heavyweight, No. 9, Noxall, World Wonder, Mortgage Lifter, White Globe, Robson's Seedling, Pioneer Rural, and Mason Rural. From the standpoint of morphological char-

*East, E. M. 1915 Journal of Heredity, Vol. 6. No. 2. Feb.

acters, all these have been indistinguishable from Carman's productions. Most, but not all, of them originated by clonal selection. Robson's Seedling came from true seed purchased from a salesman by Robson Brothers of Hall, New York. Heavyweight was tuber-unit selected and introduced by F. C. Gibbs of Fillmore, New York. No. 9 introduced by a Mr. Andrews of the firm of G. W. Hickox and Son of Batavia is of unknown origin. Mason Rural is claimed to be a seedling developed in Pennsylvania. Pioneer Rural was discovered as a mutant from Russet Rural by Fred S. Hollenbeck of Tully, New York. This and Heavyweight are the most widely grown Rural varieties in New York at the present time. The Rural varieties will persist under western New York conditions for some time because they are fairly tolerant of heat, drought, late blight, and foliage insects and because they are of better culinary quality than many of the new and old varieties."

The Committee desires to call attention to the widespread lack of uniformity which prevails in varietal nomenclature. This situation is particularly emphasized by Dr. William Stuart in the following paragraphs:

"Desirable as may be the continuance of potato nomenclature studies, it is nevertheless disheartening to those engaged in such studies to note so many failures on the part of writers to use the terminology suggested by your nomenclature committee. While fully recognizing the difficulty of supplanting the commonly accepted trade name of a variety with that of its original introductory name, it should nevertheless be incumbent upon those engaged in potato investigations to employ the proper name of a variety in papers prepared for publication. The few examples herewith given may serve to emphasize the point in question. The Russet Burbank is commonly referred to in trade papers, and frequently in Experiment Station Bulletins, as Netted Gem, Idaho Russet, or as Russets. Another example is that of the Charles Downing which is almost universally known to the trade as the Idaho Rural; a name not infrequently used in scientific publications. A third example is noted in the case of the variety Prolific which is universally known to the trade as the Brown Beauty. In this case we have an example of what happens when the identity of the variety is lost for a period of years and a local name becomes firmly established. A similar case of lost identity occurred in the case of the Peerless, which became generally known to the trade as the Pearl.

"While the procedure suggested for the re-establishment of the introductory names has been previously made by your Potato Nomen-

clature Committee it is deemed desirable to remind you again of the suggestion. If it were possible to get every scientific writer to refer to varieties under their true name rather than a trade name, when possessing such, it would eventually result in the trade's acceptance of the proper name. For example in the case of the varieties cited, it is suggested that the true name be followed by its trade name or synonyms in parentheses.

"One of the most serious confusions in variety identity is of more recent origin. This confusion is due to the application of varietal names or numbers to strains or selections from well known varieties. Examples of this sort are the Dooley, Heavyweight, and No. 9, all of which are selections from the Rural New Yorker No. 2. The validity of applying varietal names to such selections may well be challenged, especially when not even an expert can recognize any marked difference in growth habit, vine characteristics, tuber shape, or productiveness, from that of the parent variety. In view of these facts it would seem undesirable to recognize these named selections as distinct entities, and especially to grant seed certification tags bearing such names. If there is any justification for the recognition of such varietal selections, it is suggested that a different procedure be followed whereby the identity of the parent variety would be maintained. The following method is suggested: Assuming that Dooley is a selection made by a man named Dooley, it should be listed as Rural New Yorker No. 2, (Dooley's Selection), placing the selection name in parentheses. A simpler form would be to use a selection number, as for example to cite No. 9, as Rural New Yorker No. 2 (Selection No. 9). In no case should the reader be in doubt as to the parent plant.

"In the case of the Nittany Cobbler, while its parental identity is established, it is questionable whether such nomenclature is desirable, especially when no observable differences between it and the parent plant can be noted.

"A further source of confusion occurs in the Triumph, Rural and Burbank Groups. In the case of the Triumph, we have the red and white skinned and an intermediate form with splashes of red on a white or flesh-colored background. Our chief concern, however, is with the first two. The original Triumph being a red-skinned variety has been variously listed as Red Bliss, Triumph, and Bliss Triumph. It has been suggested that it be divested of all of these terms and be henceforth called Triumph without further reference to color or name of seedsmen who introduced it. In the case of the white sport of the Triumph,

it is recommended that it shall always be referred to as the White Triumph.

"The Rural and Burbank groups each contain a russet-skinned variety which has resulted in more or less confusion in trade usage. To eliminate such confusion it is suggested that these two types in each group be referred to as the Rural and Russet Rural, Burbank and Russet Burbank. Such treatment would obviate the necessity of using the descriptive terms, White Rurals or Smooth Rurals, or similarly White Burbanks or Smooth Burbanks. A further improvement in terminological usage would also result from a rigid adherence to these terms as it is not at all unusual to use the term Rural Russet instead of Russet Rural or simply the term Russet. This criticism of usage also applies to the Russet Burbank. While it is recognized that long usage of trade names is difficult to overcome, it is believed that a systematic adoption of a uniform nomenclature usage on the part of members of the Potato Association of America will eventually accomplish the object desired."

Respectfully submitted,

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E. V. Hardenburg.
C. H. Metzger.
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Wm. Stuart.

SECTIONAL NOTES

FLORIDA

The abnormally wet weather that prevailed during the last 10 days of December and the first 10 days of January delayed the planting of the major part of the Hastings potato crop for approximately two weeks. In fields planted in December and prior to the 10th of January, much seed piece rot developed and the stands were greatly reduced in low ground. Little damage resulted from seed piece rot in crops planted after the 20th of January and the fields planted after this date produced the highest yields.

The temperatures in February and March were subnormal and delayed both the germination and the early growth of potatoes. The temperatures in February, particularly, were the lowest we have experienced since 1912. Severe freezes that occurred on the 1st and 2d of March, with temperatures dropping to a minimum of 25° F. in

the coldest places, damaged the crop severely since 75 to 80 per cent of the plants had emerged. The youngest plants were killed to the ground and the oldest, which were about 12 inches in height, were killed back from 5 to 7 inches. An epidemic of late blight became prevalent in March and continued to increase in severity until the end of the first week in April when weather conditions suddenly became unfavorable for the disease and little spread occurred thereafter. Owing to these unfavorable growing conditions, particularly the severe low temperatures in March, the yields were considerably below normal. Some of the early crops averaged from 10 to 15 barrels per acre whereas one field that was planted late and irrigated during the growing season averaged approximately 100 barrels per acre. About 2,000 car loads were shipped from the 12,500 acres planted. The yield was approximately 90 bushels per acre compared with the 117-bushel average for the last 12 years (1929-1940) and the all-time maximum yield of 220 bushels per acre produced in 1940.

Our growers continued to abandon the growing of the Spaulding Rose variety and planted 94.1 per cent of the total acreage in the new varieties including Katahdin, Earlaine, Sebago, and Pontiac. (June 23).—A. H. EDDINS.

INDIANA

About the only change in the potato crop in Indiana during the past month has been for the good, since we have had very timely rains and almost ideal weather. The plants have set rather heavily and for the most part the vines are a very dark green color, showing that there is still an ample supply of fertilizer.

Harvesting of the early potato crop will start about the middle of the month and our growers are determined to put up just as good a pack, if not better, than some of the best that has ever come into the state. A number of growers are equipped with brushes and washers for the commercial trade and also hand graders and sizers to take care of the local crop. We find that in most parts of the state, with the exception of some 15 or 20 of the northern counties, practically all of the potatoes produced in this locality are consumed with little or no competition from elsewhere. From now on we will have potatoes to place on the market and from present prospects our crop will be considerably larger than it was last year. (July 12).—W. B. WARD.

MICHIGAN

Despite the dry weather which has been quite general throughout the state during June, our potato crops are looking good. The stands are good and the plants show plenty of vigor. As was stated last month the Michigan plantings show a definite reduction from last year.

Plans are being made for holding a referendum of the Federal and State Marketing Agreement on the 11th and 12th of August. Interest seems very favorable for some kind of a program and the growers are in a receptive mood for anything that will help the potato industry.

The Falk Product Co. has used about 10,000,000 lbs. of low grade potatoes in the manufacture of potato flour this past year. This potato flour is used entirely by bakers and in no way comes into competition with potatoes through the usual channels of potatoes that are consumed.

Showers were reported quite generally on the 6th and 7th of July in the late-producing sections of the state. (July 16).—H. A. REILEY.

NEBRASKA

The harvesting of early crop potatoes in the Kearney-Gibbon district of central Nebraska began the first week in July. From the standpoint of quality and yield, the crop was reported very good. This deal will probably continue for approximately a month, and shortly thereafter, early potatoes (table) will begin to be harvested in the western Nebraska area. The planting of seed and commercial table potatoes in the western, or main potato areas in Nebraska, covered practically the entire month of June. A few growers began to plant the first week but in practically all cases, had to discontinue because of the continuous rainfall during the second week. There was a delay of a full week, and in some cases, even a longer period, before planting operations were resumed. This delayed the majority of the planting about a week longer than usual, though conditions have been excellent throughout the territory in the Panhandle section, where the late main crop is grown. A few growers did not complete their planting until after the 4th of July. Even these late-planted fields are apparently in very good condition.

The few early-planted fields through the western area, that is,

April and May plantings, were found to be heavily infested with psyllids, during the month of June. This has resulted in general spraying on the early planted fields, and preparation for spraying the late fields as soon as necessary. Psyllids are favored by cool weather, of which there was an abundance until the first of July. The extremely warm weather that has been general since that time, will probably account for a reduction in the psyllid population and may check them without the necessity of spraying.

The inspection of Certified seed potatoes will begin between the 15th and 20th of July. The plants have grown so rapidly and look so well that they will probably make up for the somewhat later planting date. The acreage entered for seed certification has been reduced from 15 and 20 per cent compared with 1940. This reduction is somewhat caused by the low prices received, but to a considerable extent by the extreme drought conditions that existed during the early spring, which discouraged many growers from planting so large an acreage as usual. The favorable conditions that existed about planting time greatly stimulated the local seed trade, so that all available supplies were cleaned up before the demand was taken care of. (July 9).—MARX KOEHNKE.

NEW JERSEY

The Central Jersey potato growers have revived the Central Jersey Cooperative Potato Association, which was organized in 1933. This cooperative was set up with the idea of supplying to its members the facilities of a selling organization. This year, the organization has contracted with the Central Jersey potato dealers, who have organized a Potato Sales Company located at Hightstown to handle New Jersey potatoes from one office. Present indications are that by the time the New Jersey deal gets well under way, approximately eight-five per cent of the Central Jersey acreage will be signed up to be sold through the central office.

The chief purpose of this plan is not to set prices, so much as to prevent unnecessary price cutting, which is so prevalent when a considerable number of dealers operate from individual offices.

Present indications are that the quality of the New Jersey crop will be excellent. Some Irish Cobblers have been harvested and the size of the tubers is all that is to be desired. Opening prices were very discouraging, however, and it is obvious that unless conditions improve, the New Jersey growers, together with those from other potato-growing sections, will experience another poor season. Our

growers have become efficient producers but despite all their efforts, individually and collectively they have not been able, in recent years, to obtain returns which would make it possible for them to pay their production costs. Low prices again this year would certainly result in an all out effort to effect a control of some kind which would make it possible for them to be repaid for their efforts to produce a product which is so important a part of the diet in this country. (June 17).—WM. H. MARTIN.

NORTH CAROLINA

Nearly all the North Carolina potato crop is practically harvested at the present date, although a few more cars will roll out of this state. The shipments will be less than the anticipated 5,000 cars. Our yields were very low in some fields and in other fields above the average. The quality in general is good, except that many of the tubers are very small. All prices dropped sharply early in July but have risen again since the supply has become short. It is too early to estimate our mountain crop. (July 11).—ROBERT SCHMIDT.

RHODE ISLAND

The potato crop in Rhode Island is in excellent shape, and the season to date has been very favorable. The acreage planted is approximately the same as last year, the largest acreage consisting of the Green Mountain variety with Cobblers next. Most of our commercial growers included some Chippewas as an intermediate season crop, and many of them have also planted Sebagos. Some record yields of Sebagos were produced last year and much enthusiasm for this newcomer is being shown. It is more than surpassing the expectations that we have based on its performance in the preliminary tests in the state. (July 14).—T. E. ODLAND.

SOUTH DAKOTA

Potatoes have never looked better at this time of the year. We will have very fine fields to show on our annual tour which will take place on the 17th and 18th of July. The first field inspection is approximately completed on the 2200 acres entered for certification. One field of Burbanks, one of White Rose and two of Katahdins are entered for certification this year,—the first time for these varieties. We are

expecting to ship a few cars of early stock to Cuba early in September.

Growers are now busy dusting and spraying their fields, although insect infestation has been light this season. (July 12).—JOHN NOONAN.

VERMONT

Although our planting operations were completed earlier than usual the crop is not apparently advanced abnormally. Several weeks of dry weather and cool nights have retarded growth.

Sixty-two samples were entered in the certified seed test plot at the State School of Agriculture farm, Randolph Center. Green Mountains predominate as usual, but Katahdins, Chippewa, Houma, Cobblers and several other varieties are represented. The preliminary readings that were taken on the 30th of June, indicated generally satisfactory results in seed selection. (July 12).—H. L. BAILEY.

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REPORT ON POTATO VIRUS DISEASES IN 1940

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This report gives a review of some of the papers on potato virus diseases published in 1940. When original papers were not available abstracts found in the Review of Applied Mycology were used.

Salaman and Wortley (16) in 1938 transmitted potato leafroll by means of grafts to Mathiola and Campunala, both of which acted as carriers. In the following year the same disease was transmitted by grafting from potato to turnip and back to President potato, and by *Myzus persicae* from potato to Brussels sprouts and back to potato. Neither of the crucifiers showed any symptoms, but the virus transmitted from these hosts to President caused a typical leafroll. An unexpected complication, however, arose because of the fact that in a number of instances the virus carried over to the potato and thence to tobacco, or other hosts was not leafroll but Y. Upon examination this virus was found to be carried by the experimental potatoes, which had shown typical leafroll for nearly 20 years without a trace of the typical Y symptoms. It was definitely demonstrated that the virus Y can be carried in a masked form by turnips, cabbage, kale, Brussels sprouts, red clover, garden peas, and bindweed (*Convolvulus avensis*), and transmitted from crucifiers to potatoes by grafting or by means of *M. persicae,* and thence to tobacco and *S. glutinosum.* Brassica sp. frequently serve as overwintering hosts for *M. persicae* and it is suggested that they and

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the almost ineradicable bindweed may also act as reservoirs for some of the potato viruses during the winter.

Black (3) describes additional studies on the virus of potato yellow dwarf. Of the seven strains used, B_1 and B_2 were obtained from *Nicotiana glutinosa* plants inoculated by means of the clover leafhopper *Aceratagallia sanguinolenta* B_3 and B_7 by passing the field strain through Turkish tobacco and large rooted chicory, respectively, B_4 and B_5 from a single individual of *A. sanguinolenta* which transmitted a necrotic type variant of the virus *Trifolium incarnatum*. B_4 was similar to, if not identical with, the field strain.

On *N. rustica* the symptoms exhibited were as follows: B, produced light green, diffuse local lesions, the systematically invaded leaves turning yellow at the tip and showing vein clearing and yellow or brownish spotting over the remainder of the surface. B_4 gave rise to large, diffuse, yellow lesions, the systematically invaded leaves yellowing uniformly. B_5 produced brown lesions with necrotic, gray centers, and caused rapid leaf yellowing, extensive vein necrosis, large necrotic areas, and the death of the whole leaf. B_6, which was eventually lost, produced brown, necrotic lesions much smaller than those due to B_5. Systematic symptoms set up by B_6 were delayed, and extensive vein necrosis rapidly developed, apparently preceded by vein enlargement, the dead veins forming a raised reticulation; this was followed by large necrotic blotches and the death of the entire leaf. When systematically invaded before maturity, the plant died. B_7 formed small, light yellow lesions with irregular margins; systemic symptoms were delayed, and took the form of intense leaf yellowing. On Green Mountain potatoes all the strains caused a rather severe disease, though some set up milder symptoms than others.

Cross-inoculation studies demonstrated that *N. rustica* plants previously invaded with B_1, B_2, B_3 or B_4 were protected against systemic invasion by B_5 and could not be distinguished in this respect from the controls. When B_5 was inoculated into *N. rustica* plants previously invaded by potato ring spot, potato vein banding, cucumber mosaic, lucerne mosaic, B_2 or B_7 advanced systemic symptoms of B_5 developed on all the plants except those previously invaded by B_2 and B_7.

Of the seven strains described, only B_4 and B_5 appear at present to merit varietal names, and are accordingly named *Marmor vastans* H. var. *vulgare* n. var., and *M. vastans* H. var. *lethal* n. var., respectively.

Black (1) found that by selective breeding through 10 generations, two races of clover leafhoppers (*Aceratagallia sanguinolenta*) have been obtained, one "active," the other "inactive," under conditions where 80

per cent of the active individuals transmitted the potato yellow-dwarf virus to crimson clover, only 2 per cent of the inactive insects and 30 per cent of the hybrids between the two races transmitted. Infective individuals appeared in colonies of the inactive race, although all their ancestors for 10 generations had failed to transmit. Conversely, in colonies of the active race some insects failed to transmit despite the fact that all their ancestors for 10 generations were infective. Infective insects in the active race were more efficient vectors than infective insects in the inactive race. Male infective insects were slightly but significantly more efficient vectors than the female infective insects. A slightly but significantly higher percentage of males than females transmitted the virus. Tests with the hybrids indicated that sex-linkage may be involved in the heredity of ability to transmit.

Dykstra (6) found that Canada streak and rugose mosaic can move through the parenchyma cells of the stem, but their major movement appears to be through the phloem, and the rate of movement is influenced by conditions affecting the flow of elaborated food particles. Removing the external and internal phloem of potato and tobacco plants failed to keep the virus from passing through the ring. Keeping the inoculated shoots in darkness caused a retardation of movement into the non-inoculated part of the plant from 2 to 4 weeks and varied with individual plants. The virus can move from one shoot into another of the same plant through the vascular tissue of the seed piece, but not through the parenchyma. After 96 hours the virus can be recovered from inoculated leaflets but not from the uninoculated ones of the same plant before these develop symptoms. It requires 72 hours for the virus to move from the uninoculated leaves into the petiole and 96 hours to move into the stem. The virus can be recovered from the stem 12 days after inoculation but not before that, even if stem parts are incubated for 2 weeks after removal from the plant.

Severin (18) collected a volunteer potato plant in one of the valleys of the Montara Mountains near Montara. This plant showed purple, sessile, aerial tubers that grew from the axil of the leaves. Purple dwarfed leaves developed from the aerial tubers. Two lots of 20 previously non-infective long-winged aster leafhoppers after feeding on the diseased potato for an average of 4 days, were transferred and kept on 2 healthy aster plants that developed typical symptoms of aster yellows. It is evident from this experiment that the potato was naturally infected with aster yellows.

Smith and Dennis (21) observed a virus affecting a White Burley tobacco plant, which resembled potato virus Y, but differed from it

in certain respects. The disease was severely necrotic and superficially resembled that caused by the combined potato viruses X and Y on tobacco. Inoculations of White Burley tobacco and a number of other Solanaceous plants produced the characteristic necrosis only in some tobacco plants whereas the rest developed a vein-banding typical of virus Y. Return inoculations to tobacco yielded the necrotic disease except in the case of *Lycopersicum racimirerum* and *Salpiglossis variabilis*, from which only the vein banding constituent could be reisolated. Neither phase could be recovered from *Schizanthus retusus*, or *Solanum nodiflorum* both susceptible to virus Y. The disease was transmitted to various potato varieties both by grafting and through sap, but only from President and International Kidney was it possible to reisolate the full necrotic disease; from all others only the veinbanding phase was recovered.

The virus causing the full necrotic phase was detected in sap heated to 50° C for 10 minutes, but in a second experiment only the vein banding phase survived at that temperature. In sharp contrast to virus Y, the vein banding phase of the disease retained its infectivity at room temperature for 27 days or longer; the necrotic phase was generally lost at dilutions of 1 in 800, although it appeared irregularly even below these; the vein banding phase persisted in dilutions of 1 in 1000 but not beyond. Only the vein banding phase was transmissible by *Myzus persicae* and *Microsiphum solanifolii.* Some evidence was obtained indicating that no cross-immunity exists between the virus in question and viruses A, X, and Y. It is concluded from these data that the virus is a separate virus of a very unstable character.

Folsom and Rich (8) conducted a comparative study on the transitory symptoms of potato leafroll known as net necrosis and the nonparasitic stem-end browning in Maine, when a comparative study of the two diseases was made during the winter of 1937-'38.

Microscopically, stem end browning differs from net necrosis in its development of necrosis in both phloem and xylem; only the phloem is affected by net necrosis. Prior to 1921, net necrosis appears to have occurred only sporadically in Maine, but outbreaks of both this disease and stem-end browning were found in the state in 1923 and 1939. Up to 20 per cent stem-end browning occurred in the 1936 crop from Aroostook County. Neither trouble has so far been observed in the Katahdin and Chippewa varieties.

Stem-end browning was experimentally shown to exert no adverse effect on yield, neither has any evidence been obtained that is transmitted by the tubers. The underlying cause of the trouble would seem

to be caused by environmental conditions or a complexity of conditions in the field, but so far no correlation has been established between stem-end browning and soil type, previous occurrence in the soil, previous fertilizer treatment, hydrogen-ion concentration, or moisture, presence of virus diseases, origin of commercial strain, injury to the parent plant, time and method of digging, and certain storage conditions.

Kohler (11) continued his investigations on two strains of potato virus A, and four of the *Y* type. The representatives of the A and *Y* groups were found to differ in the following respects: *Nicotiana glutinosa* and *Solanum racemerigerum* are susceptible to *Y* but immune from A; the thermal death point is 58° C. for the Y strains as against 50° for those of A; and infection by the virus A does not protect its host against subsequent invasion by Y or conversely, though an attack by a weak strain of Y confers resistance to a stronger member of the same group. The Y *antiserum* was inactive towards the writer's two A strains but agglutinated the Y strain G.A.

Black and Price (2) found that potato calico virus and alfalfa mosaic virus produce similar but not identical symptoms on *Nicotiana glutinosa* L., *Phaseolus vulgaris* L., *Vicia faba* L., *Vigna sinensis* Endl., *Solanum tuberosum* L., *Trifolium incarnatum* L., *T. pratense, T. repens,* and *Cucumis sativus* L. Plants of *Nicotiana glutinosa* and *N. tabacum* infected with potato calico virus are refractory to infection with alfalfa mosaic virus. Potato calico and alfalfa mosaic viruses are, therefore, considered to be closely related and the potato calico strain is named *Marmor medicaginus* H var. Solani n. var. Plants affected by potato ring spot, cucumber mosaic or Canada streak are susceptible to infection with alfalfa mosaic virus. Therefore, the viruses causing these diseases are not thought to be closely related to alfalfa mosaic virus.

Schultz *et al* (17) found that on the basis of symptomatology varieties may be classified as (a) symptomless carriers, (b) necrotic, (c) light green and slightly rugose, (d) faintly mottled. On the basis of resistance to virus X, varieties may be grouped as (a) immune, (b) rarely infected, (c) easily infected.

Experience with the reaction of potato seedling varieties to virus A has shown that on the basis of symptomatology varieties may be classified as (a) necrotic, (b) light green and rugose, and (c) mottled. On the basis of resistance to virus A, varieties may be grouped as (a) immune, (b) rarely infected, (c) easily infected. Varieties are virus A immune by aphid infection, but not by graft infection. It is indicated that the necrotic reaction of some varieties to virus A by graft infection suggests that such varieties are virus A. immune by aphid infection.

The resistance reaction of the parents to virus A or to Virus X is transmitted to a high percentage of the progeny. A higher percentage of virus A or virus X resistant progeny results from resistant x resistant than from non-resistant x resistant parents. Progenies of virus X immune x virus-A immune have been produced that are immune from both viruses. Inasmuch as these two potato mosaic viruses and their strains are among the three potato mosaic virus groups that are responsible for most of the potato mosaic epiphytotics, varieties immune from both virus A and virus X will play an effective role in the control of potato mosaic.

Jones *et al.* (9) conducted further trials on the resistance of potatoes to virus diseases. Veinbanding or virus Y was found to reduce the tuber yields of the U. S. Department of Agriculture 46000, Earlaine, and Houma varieties by 75, 58, and 72 per cent, respectively, in the second season following 100 per cent infection by the virus, and that of Kathadin only by 5 per cent. None of the seedling lots showed immunity from mechanical inoculation with the virus Y; some were completely susceptible and others somewhat resistant. Some resistance was consistently exhibited by seedling lots grown from seed of which Katahdin was a parent. Katahdin selfed seedlings showed 54 per cent resistance, but higher resistances were obtained by crossing Katahdin with Ackersegen, Imperia, Sebago, and U. S. D. A. 41956. The results of field tests showed that mechanical inoculation with the virus Y in the greenhouse does not record the limit of their susceptibility since greater susceptibility was observed from natural infection in the field. Only those seedlings having Katahdin as a parent showed resistance to veinbanding in the field. When potato tubers were planted in the same planting with seedlings, many varieties became 100 per cent infected with veinbanding in 2 years, whereas seedlings 46842 and 47208 showed none, Katahdin showed 13, and several other varieties less than 32 per cent infection. The results of tests with single-drop tubers showed that selfing Earlaine or crossing it with Katahdin or U. S. D. A. 41956 gave seedlings of reduced resistance to the Y virus as compared with those obtained from selfing Katahdin or crossing it with No Blight or U. S. D. A. 41956. No evidence was found that the Y virus is seed-transmitted. The beet curly-top virus appeared in potato planting in 1938 and 1939, characterized by dwarfing and erectness of the plants, rolling, harshness, and reddening of the foliage, and increase in the number of tubers. Healthy tomato scions grafted on affected potato plants developed typical symptoms of curly top.

Selfed Katahdin seedlings were susceptible to infection by the

tobacco mosaic virus through grafts with mosaic-affected tomato scions, but the virus was not transmitted through tubers collected from affected plants.

Cockerham (5) conducted studies in Scotland on the carbohydrate and nitrogen metabolism of the leaves and petioles of healthy President and Arran Victory potato plants, and others of the same varieties infected with potato virus X, and showed that although comparisons among carbohydrate variations over diurnal and seasonal periods establish a similarity in the gross metabolism of carbohydrates in normal and mosaic leaves, definite, if slight modifications of the fundamental metabolism may arise as a result of mosaic infection. At every stage of the diurnal investigations the diseased lamineae had lower starch values than the healthy ones. Slight differences in carbohydrate variations consistently indicated impediment in starch formation and hydrolysis in affected leaves. There was also evidence of interference with the utilization of sugar in the early growth stages, when the affected leaves were actively engaged in tissue synthesis. This change in metabolism merely preceded, however, a similar change in healthy leaves, and subsequently the only difference between the diseased and healthy leaves in this respect was in the slightly reduced amounts of carbohydrate and a persistent interference with starch elaboration in the mosaic leaves.

The slight disturbances observed in diurnal carbohydrates metabolism in the mosaic leaves would appear to be caused by two possible causes: (a) Pathological changes brought about by the virus in the mottled areas; (b) disturbances affecting primarily the growth activities of the diseased plant leading to a diminished demand for carbohydrates required for growth. A significantly larger nitrogen content was found in diseased leaves at all stages of growth, and it is possible that the pathological symptoms and retarded growth activities, which give rise to disturbances in carbohydrate metabolism, may result directly from a disorganized nitrogen metabolism.

Loughnane (13) found that from 16 healthy potato plants colonized with *Myzus ornatus* from a leafroll source, 10 developed leafroll. In two tests of the insect as a vector of virus Y, 5 out of 16 healthy potato plants colonized became infected with this virus. As the insect has been found only to a very slight extent feeding on field crops in Eire, it is probably unimportant as a vector of potato viruses under field conditions. It has, however, been observed on a wide range of hosts, and may, therefore, act as a vector of viruses of other crops.

Quanjer (14) summarizes outstanding contributions to the knowledge of the biology of the peach aphid *Myzus persicae,* with special

reference to its activities as a vector of virus diseases of potatoes and other crops. The virtual absence of serious virus diseases from Estonia, according to a recent report by W. Roots to the Dresden Agricultural Congress, 1939, has been attributed to the mean low annual temperature 4.9° C. as compared with 9° C. in Holland, the intensive breeding and selection work in progress at Jögeva, and the stringent enforcement of quarantine regulations for import. The possibility of reducing aphid infestation in Holland by the official restriction of peach and apricot growing is briefly considered.

In an address delivered at the seventeenth annual general meeting of Fellows of the National Institute of Agricultural Botany at Cambridge Salaman (15) reviewed the work done by the Institute during the years 1918 to 1938 in connection with potato diseases. It is stated that in most years from 30 to 50 per cent of the potato crop of England is severely infected wih virus diseases, the losses amounting to at least 1,000,000 tons a year. None of the existing varieties is immune from, or even fairly tolerant of leafroll, although Great Scott, and Up-to-Date are more resistant than others; and none is immune from virus Y, although a varying degree of susceptibility is found, and Ulster Monarch and Edgecote Purple are almost tolerant. There is no hope at present of breeding a variety immune from virus Y, and the key of the problem of control lies, therefore, in the use of clean seed. The author emphasizes the importance of introducing into the breeding stocks blood from wild or even unrelated tuber-bearing species of Solanum. He considers that the highest possible production of potatoes can only be obtained by the use of virus-free seed.

Cockerham (4) states that since the introduction in 1932, by the Department of Agriculture for Scotland, of a scheme whereby virus diseases are taken into consideration in grading potatoes for seed purposes, a steady improvement in the health of Scottish stocks has resulted. Nevertheless, virus diseases still continue to harass the Scottish seed potato industry, especially potato virus X. This virus is independent of insect vectors for dissemination, and the environmental advantages for potato seed production offered by the greater part of Scotland do not come into play. Consequently a large acreage of potatoes has to be graded H_1, which in the absence of virus X would have been graded A. It is suggested that the replacement of varieties tolerant to this virus by intolerant or "field immune" ones may provide a solution to the problem.

Silberschmidt (19) gives particulars on the progress to date and future plans in regard to the scheme already described for the produc-

tion of virus-free seed in Brazil. The project is organized on a cooperative basis by nearly 30 growers with properties situated at an altitude of 1,000 meters or above in the region of Sao Joao de Boa Vista. About one-half the seedlings raised from the 2,000 boxes of Eigenheimer and Bintje seed imported from Holland developed symptoms of virus diseases, necessitating drastic roguing and convincing the farmers of the urgent need for the establishment of plantings for the production of indigenous seed stocks. In this connection the method adopted in various countries for the realization of this object are described and their application to local conditions discussed.

Silberschmidt (20) discusses the objectives of a cooperative society having been founded in the Argentine for the production of home-grown seed potatoes. Seed should be secured from a reliable source, and planted in a suitable locality, such as the mountainous region of Cascata, where the humid climate is particularly favorable for this purpose.

In addition to the three European varieties commonly cultivated in Argentine namely, Eigenheimer, Bintje, and Konsuragis, a considerable trade is carried on with indigenous stocks. The Argentine potatoes suffer severely from virus diseases, but they possess valuable commercial qualities and bring high prices on the Rio de Janeiro market. In their cultivation it is necessary to practice rigorous roguing. Directions for the control of virus diseases include the eradication from the vicinity of the breeding plots of all other Solanaceae and the restriction of cultivation of peaches and other crops liable to harbor aphids. In order to prevent the transmission of infection by aphids from diseased to healthy tubers in storage, the bins should be fumigated, while the potatoes are still in the dormant state, with 98 per cent nicotine, using a minimum quantity of 2.5 c.c. per 10 cubic meters.

Kramer (12) gives a brief survey of the various theories advanced in explanation of the problem of potato virus diseases, and discusses the possibilities of combating the trouble in the Argentine by suggesting four general measures of control: (1) the stimulation of vigorous growth by spraying against insects and fungi, (2) the procurement of seed from mountainous regions where humid conditions and strong winds prevail during the growing period, (3) clean cultivation, crop rotation, elimination of susceptible wild Solanaceae, and (4) prompt roguing of diseased plants in lots used for seed, and the use of certified seed from an approved source.

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SPECIFIC TRANSMISSION OF VARIETIES OF POTATO YELLOW-DWARF VIRUS BY RELATED INSECTS

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During each of the past three years, leafhoppers of the species *Agallia constricta* Van Duzee[1] collected in New Jersey were found to be carrying a strain of the potato yellow-dwarf virus (*Marmor vastans* H.)[2]. This variety of the virus will herein be referred to as the New Jersey variety, in contrast to the variety *vulgare* (1), originally described from New York State and known to be transmitted by another Agallian leafhopper, *Aceratagallia sanguinolenta* (Prov.).

After preliminary experiments indicated that *Agallia constricta* did not transmit the New York virus, a test was conducted to determine whether or not each variety of the virus was transmitted by one of the leafhoppers but not by the other. A mixture of nonviruliferous nymphs of *Aceratagallia sanguinolenta* and *Agallia constricta* was placed on each of 3 crimson clover plants (*Trifolium incarnatum* L.). One plant was affected by the New York variety of virus, one by the New Jersey variety, and the third was healthy. The insects were allowed to feed for 20 days. Then they were removed, the leafhoppers from each plant separated into two groups according to species, and single nymphs were placed on individual crimson clover seedlings. Each insect was tested on 3 successive clover seedlings over a period of 8 weeks unless it died before the completion of the experiment. The seedlings were kept under observation for 6 weeks after removal of the insects. As shown in the table, the New York variety of virus was transmitted only by *A. sanguinolenta*, the New Jersey variety only by *A. constricta*. The results indicate that there exists a high degree of specificity, perhaps an absolute specificity, in the relationship between the two varieties of virus and the two related leafhoppers.

The closeness of relationship between the leafhoppers may be judged from the fact that as late as 1931 DeLong and Davidson (3) treated them as different species in the same genus. However, in 1933

[1]Identified by P. W. Oman.

[2]Viruses in this paper are named according to the system of nomenclature in the Handbook of Phytopathogenic Viruses (1).

TABLE 1.—*Transmission of two varieties of potato yellow-dwarf virus by two different Agallian leafhoppers*

Condition of Plants on Which Insects Fed Before Being Tested	Ratio: Number of Infective Insects / Number of Insects Tested		Ratio: Number of Plants Infected / Number of Test Plants	
	Aceratagallia sanguinolenta	*Agallia constricta*	*Aceratagallia sanguinolenta*	*Agallia constricta*
Infected by N. Y. virus	11/31	0/31	17/82	0/86
Infected by N. J. virus	0/35	19/35	0/103	43/103
Healthy	0/33	0/33	0/90	0/94

Oman (5), in his comprehensive taxonomic treatment of the Agallian leafhoppers, placed them in different, closely related genera.

That the New Jersey virus is a variety of the potato yellow-dwarf virus was indicated by a study of symptoms. The differences in the effects produced by the two viruses on crimson clover, *Nicotiana rustica* L., *N. glutinosa* L., and *Solanum tuberosum* L. var. Green Mountain were minor but, nevertheless, consistent and easily recognizable. Whereas the New York virus produced a characteristic clearing of the veins and yellowing in the younger leaves of crimson clover, the New Jersey virus produced a rusty brown necrosis of the veins and yellowing, usually in the older leaves. The New Jersey virus produced much less conspicuous primary lesions on inoculated *N. rustica* leaves than the New York virus. It appeared to be less invasive than the New York virus in both crimson clover and *N. rustica.*

In two experiments, New Jersey virus protected *N. rustica* plants against the *lethale* (1) variety of New York virus. Out of a total of 16 plants invaded by any one of four different isolates of New Jersey virus, 13 failed to develop any of the systemic necrotic symptoms caused by the *lethale* virus and 3 developed them two to four weeks after the controls. Furthermore, all 3 of these plants had been inoculated by a New Jersey isolate judged from its symptoms to be a weaker invader than the other isolates. Controls inoculated by the *lethale* virus consisted of healthy plants and plants previously invaded by one of the following unrelated viruses, tobacco ringspot (*Annulus tabaci* H. var. *virginiensis* H.), potato calico (*Marmor medicaginis* H.

var. *solani* Black and Price (2), or tobacco streak (*A. orae* H.). The plants invaded by the unrelated viruses developed the necrotic systemic symptoms of the *lethale* virus at approximately the same time as the previously healthy plants. These cross-protection tests clearly indicate that the New Jersey and New York viruses are varieties of the same virus species.

Because of the specific transmission of the New Jersey virus by a species of *Agallia,* it is proposed that it be named *Marmor vastans* H. var. *agalliae* n. var.

The specific relationship between the two varieties of yellow-dwarf virus and their insect vectors evokes comparison with certain highly specialized parasites, as, for example, the rust fungi. In some rusts, races of the same morphologic species show extreme specialization with respect to the related hosts which they attack. In such instances there is little doubt that the races have a common ancestry and that their evolution has occurred during long and intimate association with their hosts. The specialization of the two varieties of potato yellow-dwarf virus towards two Agallian leafhoppers is a parallel case and suggests that a common ancestor of the two leafhoppers may have transmitted a common ancestor of the two varieties of the virus. Subsequent differentiation of the leafhoppers may have been accompanied by differentiation and specialization of the virus. In the present state of knowledge other hypotheses are, of course, tenable, but the origin of the specific transmission of such closely related viruses by two related insects through some evolutionary process seems more probable than that the situation is fortuitous.

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MINOR ELEMENT STUDIES ON POTATOES IN MAINE[1]

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INTRODUCTION

The study presented in this paper was made to determine what effect the addition of certain of the so-called minor or secondary elements might have on the growth and yield of potatoes when grown on Caribou loam in Aroostook County, Maine. The study was an outgrowth of the serious magnesium deficiency that developed about 10 to 12 years ago in Caribou loam, the leading potato soil in Aroostook County. Insofar as the magnesium deficiency was concerned remedial measures from a practical standpoint proved to be fairly simple. These consisted in (a) the addition of an available magnesium compound, such as calcined magnesium sulphate, to the potato fertilizer; (b) the application of finely ground dolomitic limestone directly to the soil as a means of counteracting excessive soil acidity and supplying magnesium; and (c) a combination of both (6).

Boron, copper, iron, manganese, and zinc are recognized as elements necessary for the proper functioning of green plants (10). Increased crop yields have resulted under certain conditions with the application of salts of these elements (1, 2, 4, 5, 7, 8, 11, 12, 13).

For these reasons it seemed advisable to determine whether these elements are furnished in satisfactory quantities by the soil or whether the addition of these elements would increase the yield of potatoes on Caribou loam.

OUTLINE OF EXPERIMENTAL STUDY

Field experiments were conducted to compare a common fertilizer mixture with the same mixture plus a minor element. The sulphate salt of the elements copper, iron, manganese, nickel, and zinc was used

[1]Conducted cooperatively in Aroostook County, Maine, by the Maine Agricultural Experiment Station and the Bureau of Plant Industry, U. S. Department of Agriculture.

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at the rate of 100 pounds per acre in 1932; 25 and 50 pounds per acre 1933 to 1936; and 12.5 and 25 pounds per acre in 1937. From 1932 to 1936 inclusive ten plots consisting of single 50-foot rows of each treatment were used and arranged in the randomization method. The treatments were hand-spread in furrows on either side of a ridge, made by opening discs, in such a way as to simulate two bands when the potato planter split the ridge.

Some mixing of the fertilizer with the soil occurred so that some of the fertilizer or fertilizer-plus-element mixture may have come in contact with the seed pieces. To prevent possible contact of the mixtures with the seed pieces in the 1937 experiment and to simulate commercial practice the treatments were applied by machine in the conventional side placement band method. Six randomized plots of single 200-foot rows were used per treatment in this year. Two leading varieties, Irish Cobbler and Green Mountain, were grown, the latter variety in all tests except on Farm E in 1935 and Farm F in 1937. Ten tests were made during the five-year period (Table 1).

The results of the boron tests are given in table 2. The 1936 boron experiment consisted of ten 50-foot single-row plots of each treatment. The fertilizer and fertilizer-borax treatments were hand-spread as mentioned previously. Injury definitely occurred with an application of 5 pounds of borax per acre when the fertilizer-borax mixture was hand-spread and planting was done immediately. In this method of applying treatments, the borax may have come in contact with, or was very close to, the seed piece. To avoid possible contact of the borax with the seed piece the treatments were applied with a potato planter in the conventional 2-band side-placement method in 1937 to 1939 inclusive. Six randomized 200-foot single-row plots of each treatment were used.

In all these experiments the plots were arranged so that the Analysis of Variance Method could be applied to the data to determine their significance.

Discussion of Results

Copper, zinc, and particularly nickel had a very depressing effect upon the yield of potatoes when the sulphate salt of these elements was applied at the rate of 100 pounds per acre. But the yield was not significantly affected by an application of 100 pounds of manganese sulphate.

Not a single case of significant variation from the check plots occurred

TABLE I.—*The influence of copper, iron, manganese, nickel and zinc sulphate upon the yield of potatoes*

(Experiments conducted on Caribou loam, Aroostook County, Maine)

Treatment		1932		1933		1934		1935		1936		1937	
		Farm A	B	B	C	B	D	B	E	B	E	B	F
		Bus.		Bus.		Bus.		Bus.		Bus.		Bus.	
Check (a)		404	281	480	411	471	462	345	275	554	345	581	337
Plus $CuSO_4$(b)	12.5 lbs.											611	351
	25			449	423	490	425	341	252	557	341	576	353
	50			449	400	495	399	342	233	523	316		
	100	344	191										
Plus $FeSO_4$(b)	12.5 lbs.											609	344
	25					482	460	343	261	548	350	559	339
	50					492	455	372	259	560	331		
	100												
Plus $MnSO_4$(b)	12.5 lbs.											532	349
	25			473	413	478	460	334	270	570	342	539	338
	50			486	402	490	443	352	274	554	342		
	100	411	288										
Plus $NiSO_4$(b)	12.5 lbs.											481	329
	25			391	355	436	338	309	179	508	298	457	299
	50			362	277	408	291	305	130	445	249		
	100	231	70										
Plus $ZnSO_4$(b)	12.5 lbs.											608	353
	25			493	428	480	437	371	273	578	349	551	359
	50			477	405	470	432	358	235	544	360		
	100	375	237										

(a) 2000 lbs. 4-8-7 per acre.
(b) Pounds per acre rates. In addition to fertilizer as under (a)

TABLE 2.—*The influence of boron upon yield of potatoes*

Treatment	1936(c)		1937		1938			1939	
	Farm A	B	A	C	C	D	E	C	E
Check (a)	554	345	581	337	336	346	382	213	388
Plus Borax (b)									
2.5 lbs.	544	333	579	375	342	356	379		
5.0	381(c)	280	591	376	333	342	400	198	391
10.0					332	353	341	196	375
20.0								186	356

(a) 4-8-7 at 1 ton per acre in 1936, 1937 and Farm E. 1938. 8-16-20 at 1000 pounds per acre at other farms in 1938 and 1939.

(b) Pounds per acre rates. Source of boron—ordinary borax.

(c) Fertilizer hand-spread in 1936. Possible contact of fertilizer-borax mixture with seed piece. Apparent toxicity of 5-pound rate. 1937-1939 treatments applied by machine, two-band side placement method.

with hand-spread applications of 25 and 50 pounds per acre rates or the machine applications of 12.5 and 25-pound rates of copper, iron, manganese and zinc sulphates.

The application of these particular elements has influenced plant growth under certain conditions, chief among which is a neutral or alkaline soil reaction, particularly true with respect to iron and manganese, and on peat soils inherently low in these minor elements. In view of the fact that the pH of the Caribou loam on which these tests were conducted averaged about 5.0 the occurrence of a deficiency of iron or of manganese appears unlikely. Apparently the copper present in the soil either naturally or from spray residues is ample to meet the requirements of the potato plant for this element.

Nickel sulphate reduced the yields of potatoes at all the rates used. Even the lowest rate, 12½ pounds per acre, produced a significantly lower yield on one of the two farms upon which it was used. Larger amounts resulted in serious reductions in yield, indicating that nickel is quite toxic to potato plants. Since all the elements were added in the form of sulphates, it is apparent that the injury is caused by the specific action of the nickel ion itself. That nickel proved to be decidedly injurious during germination and later growth was quite obvious from the retarded emergence and subsequent stunted growth particularly where higher amounts of nickel sulphate were applied.

In 1936, when the fertilizer-borax mixtures were applied so that the mixture had a chance to come in contact with or was near the

seed piece, the addition of borax at the rate of 5 pounds per acre caused a significant decrease in the yield of potatoes of 18 per cent on one farm and 34 per cent on the other. The 2.5-pound rate of borax treatment decreased the yield but not significantly.

In 1937 when the fertilizer-borax mixtures were applied by machine in the two-band side-placement method, a significant increase in yield was produced on one of two farms with both the 2.5 and 5.0-pound per acre borax treatments. This did not follow in 1938 since no significant variation from the check plot was found on three farms for 2.5, 5 and 10-pound rates.

In 1939, the 5-pound borax treatment produced a significantly lower yield on farm C but no significant variation from the check on the other farm. The 10-pound application caused a reduction in yield on both farms, again a significant decrease on farm C. The 20-pound application significantly depressed yields on both farms.

Summary and Conclusions

In 1929, potato growers in Aroostook County, Maine, were confronted with a shortage of available magnesium in the soil which proved to be a serious detriment to growth and subsequent yields of potatoes. The remedy which was simple and easily applied was to include an available magnesium compound in the potato fertilizer mixture and to supplement with light applications of dolomitic limestone to reduce the acidity of the soil as well as to increase the magnesium supply. Soon after the remedy came into use it was practically impossible to locate a field of potatoes suffering from magnesium-hunger in Aroostook County.

The question then arose as to what effect the addition of other so-called minor elements to the fertilizer mixture would have on yield of potatoes. Comparative field studies were conducted on Caribou loam. Copper, iron, manganese, nickel, and zinc sulphates were added to a potato fertilizer in the years 1932 to 1937 inclusive; and boron, as borax, was added to a fertilzer mixture, 1936 to 1939 inclusive.

The results obtained indicate that comparatively small amounts of boron and nickel added to fertilizer may be toxic to potatoes. The addition of small amounts of zinc indicated a tendency, though not significant, to increase potato yields. Manganese, iron, and copper, added to the fertilizer in the amounts used, had little or no effect on potato yields. In general it is concluded that at the present time there is no need for the addition of any of the above elements to fertilizer used for growing potatoes under Aroostook County conditions.

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INFECTION OF FIRST-YEAR POTATO SEEDLINGS WITH *FUSARIUM SOLANI* VAR. *EUMARTII*[1]

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The testing of potato plants grown from seed tubers for resistance to fusarium wilt, either in the field or in the greenhouse, has many disadvantages in a breeding program. In the field the percentage of infection with *Fusarium solani* var. *eumartii* is usually so low that a large number of escapes occur when growing single seedling plants and this seriously interferes with a breeding program. In the greenhouse a much higher percentage of infection can be obtained but the number of plants which can be grown to maturity is limited, owing to the space requirement and cost. The testing of first-year seedlings in the greenhouse would permit the use of large numbers of plants and a high degree of elimination of susceptibles, if the typical disease could be produced

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in the seedlings. As no information on the infection of first-year seedlings was available, the following experiments were conducted to determine the efficiency of this method of testing.

In preliminary tests potato seedlings, about 1 to 2 inches tall, transplanted into inoculated soil developed all the characteristic symptoms of the disease. The leaves of the infected plants developed the yellowish mottling and bronzing which commonly occurs in the field. Vascular discoloration of the underground stem occurred and necrotic flecks were present in the pith extending to the uppermost leaf. These flecks were more easily discernible by transmitted light in these young seedlings than in large plants grown from seed pieces with the deeper green coloration of the stems. The stolons showed vascular discoloration and the small tubers, if the plant survived to produce tubers, showed typical stem-end rot or vascular discoloration. All of the symptoms which appear in the field occurred in these small seedlings.

Tests of different mixtures of compost, soil, sand and gravel were then made, to determine which would produce the maximum amount of infection. It was found that a mixture of approximately four-fifths composted sod soil and one-fifth sand by volume resulted in a high percentage of infection when inoculum was added soon after sterilization.

The routine procedure was then established of sterilizing the mixture in a large soil sterlizer at 5 pounds pressure for 1 hour. After cooling, the inoculum was added at the rate of 1½ pints to 1 cubic foot of soil. The inoculum was grown in a mixture of one pint of gravel, ½ pint of soil, 1½ tablespoonful of bran, 7 grams of sucrose, and sufficient water to provide for good growth of the fungus. One and one-half pints of this mixture in quart milk bottles were found to give rapid and luxuriant growth of the organism and its addition to the soil did not cause the bad effects often resulting from the addition of inoculum containing large quantites of organic matter.

The well-mixed inoculated soil was used either in flats or in the open bench, the seedlings being spaced 2 by 3 inches. Under conditions in Lincoln, Nebraska, it was found advisable to start the seedlings in flats during the latter half of August and transplant them into the inoculated soil in September. The tubers of the surviving plants could then be harvested in time for planting in the field the following summer or they could be held in good condition for further greenhouse tests the next fall.

In the experiment summarized in table 1, seedlings from 6 different crosses were tested as described above. Typical symptoms appeared about 30 days after transplanting. The plants were examined twice a week and all infected ones were removed as soon as they showed defi-

TABLE I—*Record of tests for fusarium wilt resistance in first-year seedlings and their progeny*

TABLE I.—*Record of tests for fusarium wilt resistance in first-year seedlings and their progeny*

Cross No.	Greenhouse Tests						Field Tests[2]		
	Inoculated Sterilized Soil			Inoculated Non-sterilized Soil			Inoculated Field Soil		
	First-year Seedlings			Second-Year Test of Surviving Clones[1]			Third-Year Test of Surviving Clones		
	Tested	Infected	Healthy	Tested	Infected	Healthy	Tested	Infected	Healthy
	Number	Number	Number	Number	Number	Number	Number	Number	Number
NX-242	28	12	16	6	4	2	3	1	2
NX- 97	13	5	8	4	4	0	1	0	1
NX- 72	40	18	22	9	7	2	2	0	2
NX- 8	12	6	6	4	3	1	3	0	3
SM 7-2	54	39	15	5	4	1	2	0	2
SM 2-1	194	170	24	5	4	1	1	0	1
Total	341	250	91	33	26	7	12	1	11

[1]The 33 clones involved a total of 130 plants.

[2]Irish Cobbler and Bliss Trumph checks interplanted in 5-hill units with the seedlings showed 20 and 21 per cent tuber infection, respectively, whereas the 12 clones comprising 53 plants produced 221 tubers only one of which showed symptoms. The data from the field test are based entirely on tuber symptoms.

nite symptoms. Most of the remaining plants were mature at the end of 4 months when they were dug. All tubers were examined for stem-end rot or vascular discoloration. A large number of plants died from causes other than fusarium wilt[2] and only those plants which could be definitely recorded as either healthy or infected are included in table 1. Seventy-three per cent of the seedlings became infected. This is about the same amount of infection that occurs when Bliss Triumph plants are grown from seed pieces under similar conditions. Many of the healthy plants failed to produce tubers of sufficient size for planting or were discarded because the tubers were of undesirable type.

The tubers from 33 of the surviving seedlings were planted the next winter in units of 2 to 5 hills each, in inoculated non-sterilized soil in the greenhouse. Evidently many of these had simply escaped infection in the first year's test since 26 of the 33 clones had one or more plants infected. The clones which remained healthy and some of those showing very slight symptoms, were planted in inoculated soil in the field the following summer. Twelve of these comprising 53 plants were grown and only one developed the disease. The infection in this clone was limited to one tuber out of 14 produced on 4 plants. The check units of Triumph and Cobbler averaged about 20 per cent infection.

In an additional test planted in the greenhouse in 1939, 21 selfed or hybrid lines comprising about 4,000 plants averaged 53 per cent infection. The different lines, however, varied from 20 to 90 per cent infection. In a test being conducted at the present time, a similar wide variation in susceptibility is evident.

Conclusion

The testing of first-year seedlings for fusarium wilt resistance in the greenhouse has proved to be a satisfactory method of eliminating susceptibles. It overcomes the disadvantages of the high expense of growing plants from tubers in the greenhouse and reduces the large number of escapes that often occur in the field. The symptoms of the disease are as clearly defined in the small seedling plants as in plants grown from tubers. Although seedlings of desirable horticultural quality may be lost, the high percentage of infection obtained in all crosses tested to date would indicate that the chances of obtaining resistant seedlings after selection has been made for other characters would be slight. The number of tests to date has been limited but the results indicate that the desirability of parent stock for fusarium resistance can be rapidly determined by this method.

[2]Further tests are being made using nutrient solutions with gravel culture and inoculation after the seedlings have become established in an attempt to decrease the mortality due to causes other than fusarium wilt, and to produce larger tubers than were developed in the soil.

SECTIONAL NOTES

IOWA

An attack of late blight has occurred in Minnesota and Iowa. This area has experienced six weeks of moist cool weather ending suddenly about the 15th of July. This period was followed by an extremely hot dry spell for several weeks.

About the 10th of July many leaves were wilting as a result of Phytophthora, and had the weather not changed as it did it is probable that most of the unsprayed vines would have been killed. As it was, only slight damage was incurred.

The region near and north of Lake Superior often has mild to severe attacks of both this blight and the rot, but Iowa because of its warmer temperatures seldom has an outbreak of these diseases. The last severe loss was encountered in 1915,—twenty-six years ago. (Aug. 14).—C. L. FITCH.

MAINE

Growing conditions in Maine this season are spotty. Some sections are very dry; others are too wet with plenty of blight in evidence as might be expected and in still other places we find nearly optimum conditions prevailing. On the whole, however, the crop is in good condition at this time (middle of August).

Aphids have been showing up the past two weeks in considerable numbers, but the rains during this week throughout most of Aroostook have inflicted considerable damage on them. The winged aphids are just beginning to appear.

It is doubtful if much dissemination of the virus disease has taken place to date. What will happen from now on is entirely problematical but we are hoping for the best. Bacterial Ring Rot is just beginning to show in commercial fields. With this disease there is no method of telling what the future will bring. We do know that in disinfecting, growers observed more precautions last spring than ever before and we are hopeful there will be less rejections for certification than has been true in previous years.

The benefits of our foundation seed program, supervised by the Maine Agricultural Experiment Station, are more in evidence this year than ever. In fact, we have a foundation upon which to fall back if any serious spread of disease occurs such as we have never experienced.

This enables the seed industry to obtain invariably a supply of seed of the best quality for commercial production grown in the state of Maine. It may not always be enough, as is the case this year, but it does furnish a very substantial backlog upon which to work.

The entry for certification was next to the highest on record, totaling 38,500 acres. The acreage passing first inspection is 24,400 acres or in other words a reduction of 37 per cent. The biggest reduction has been in the Cobbler, Green Mountain and Chippewa varieties.

There has not been much business in "futures" on Certified seed as yet. There is considerable interest developing and we are finding many customers visiting us at this time. Conditions have been so unsettled, accompanied with so many uncertainties in transportation, supplies of seed available and other unknown factors that both buyers and producing interests have been reluctant to do much business.

More hay has been placed in storage this summer than for a long time because of the hay shortage in other parts of the northeast due to drought. It would seem that there is a goodly supply of hay available for dairymen who may need it elsewhere.

The labor situation appears to be a serious one but somehow we have planted and produced the crop thus far without too much difficulty and we are confident that some way will be found to harvest it successfully. (Aug. 14).—Frank W. Hussey.

MICHIGAN

During the past two weeks of July, Michigan has experienced an unusually dry period with extremely high temperatures. Some showers have given temporary relief, but very favorable weather will be necessary from now on, and throughout the balance of the season to make a good crop.

The early crop yields are disappointing for the potatoes are rather small. However, the quality is very good.

The Marketing Agreement hearing held at Cadillac, Michigan, on the 11th and 12th of August, was well attended. The testimony taken indicates that the Michigan growers and shippers would favor a Marketing Agreement. (Aug. 15).—H. A. Reiley.

OHIO

The discontinuing of potato production by the small grower has resulted in a reduction in the potato acreage in Ohio of nearly thirty thousand acres during the past five years. This reduction is largely

offset by larger yields of the commercial growers. The acreage this year is somewhat less than a year ago but larger yields will practically offset the acreage reduction.

The early potatoes are now being harvested and many yields average 250 bushels or more per acre. The large local production has been responsible for low prices. There has been a tremendous shift from early to late potatoes in Ohio for the past few years, and the late crop will not be large because of the hot dry weather we have experienced during the last month. Many fields show poor stands and spindly growth.

The early crop shows considerable scab, and Bacterial Ring Rot has also made its appearance. It is too early to estimate the damage from these diseases.

The potato marketing program, developed by the growers in 1940, is now getting under way and it is hoped that this program will soon stabilize prices. It is expected that a large quantity of potatoes will be packed in paper in Ohio this year. (Aug. 14).—Earl B. Tussing.

PENNSYLVANIA

So far as present conditions are concerned, I have examined a large number of fields in northern and western Pennsylvania during the past two weeks and would say that conditions to date are good, but that the weather is becoming too dry in many sections. Unless the growers have a rainy period soon the crop will be materially reduced. I have not had an opportunity to check up conditions in the eastern part of the state. However, I know that, at present, it is dry in many sections, and that the extreme heat, together with the dry weather, has been unfavorable for the potato crop. (Aug. 12).—J. B. R. Dickey.

We are now completing our first inspection for certification. Seed fields, in general, look good although the stands are poor. Plant growth in the seed-growing areas has been good, especially in the Potter County area where there has been an abundance of rainfall. The prospects for a good crop of seed in this area are very promising at this time. Late blight has appeared in many fields in the Potter area. No damage has resulted, however, to the present time.

The varieties entered for certification, by acreage, are approximately as follows: Russet, 800; W. Rural, 265; Katahdin, 216; Nittany Cobbler, 95; Houma, 54; Chippewa, 50; and other varieties, 70.

The acreage entered this year—1,550 acres—is approximately 275

acres less than in 1940. Fewer rejections are being made, however, this year than were made during 1940. Diseases have been running somewhat lower and we anticipate that a larger acreage will be finally certified than we accepted last year. Approximately 815 acres were accepted for certification during 1940.

At a recent Field Day held at Camp Potato, approximately 500 persons attended the christening ceremonies in connection with the naming of a new potato variety. A seedling developed at Camp Potato near Coudersport, by Dr. E. L. Nixon, was named the Allegheny Mountain. This is a white skin potato with a vine growth that is somewhat decumbent. It is a green stem variety, has a purple blossom and matures medium late.

Potato growers in the southeastern part of the state are harvesting a good early crop. The yields are high and the market quality is generally reported as being above the average. (Aug. 12).—K. W. LAUER.

RHODE ISLAND

The harvesting of early potatoes has begun. Our yields, on the average, are light. The dry weather during the month of May apparently gave them so slow a start that they never caught up with the season. The crops in a few fields are turning out well but these are exceptions. The late crop is still looking good and, with favorable weather conditions, should make a satisfactory yield. The best Cobblers are selling at $1.25 per cwt. (Aug. 13).—T. E. ODLAND.

BRIEF ARTICLES

The sixth annual meeting of the High Plains Potato Conference was held at Laramie, Wyoming on the 8th, 9th, 10th of August. About fifty potato workers from at least eight different states were present.

Mr. W. A. Riedl, assistant Professor of Agronomy, University of Wyoming, was in charge of the arrangements and acted as chairman of the discussion meetings.

After the registration of the visitors, a picnic lunch was served by the wives of the department staff at the Agronomy Farm near Laramie. The afternoon was spent inspecting potato experiments of a varied nature, on the Agronomy Farm. These experiments were as follows: Irrigation by J. K. Cykler; fertilizer studies by T. J. Dunnewald; breeding and psyllid control by W. A. Riedl and ring-rot tests by G. H. Starr.

Late in the afternoon the group drove up to the University Summer Camp located forty miles west of Laramie in the Snowy Range mountains with an elevation of 10,000 feet. The remainder of the day, as well as the following day, was spent in panel discussions on many phases of potato production. The subjects of discussion, together with the discussion leaders were as follows: Potato Insects—R. L. Wallis, Assistant Entomologist, U. S. D. A., Scottsbluff, Nebr.; potato scab—L. A. Schaal, Associate Plant Pathologist, U. S. D. A., Greeley, Colo.; potato storage—A. D. Edgar, Agricultural Engineer, U. S. D. A., Scottsbluff, Nebr.; prevention of mechanical injury—Dr. H. O. Werner, Professor of Horticulture, University of Nebraska, Lincoln, Nebr.; potato ring-rot—Dr. T. P. Dykstra, Plant Pathologist, U. S. D. A., Washington, D. C. Other potato diseases—Dr. R. W. Goss, Head Department of Plant Pathology, University of Nebraska, Lincoln; potato breeding—Dr. F. A. Krantz, Professor of Horticulture, University of Minnesota, St. Paul, and potato improvement and certification problems—Dr. J. G. McLean, Department of Horticulture, Colorado State College, Fort Collins.

The discussions, although very informal, were well organized by the leaders in charge, many of whom had previously assigned to other men in the field a particular topic dealing with the general subject. The discussions were lively, interesting and well attended, especially the ones introduced by Marx Koehnke, Certification Official from Nebraska, dealing with a proposed ring-rot tolerance instead of the present zero tolerance. There was much frankness of opinion and an apparent difference of opinions on the subject. Dr. T. P. Dykstra defended the stand taken by the national ring-rot committee whereas Dr. R. W. Goss, also a member of this committee, disagreed with him as did other Nebraska and Wyoming workers. Finally, a vote was taken and the results showed that more were in favor of a small tolerance than were in favor of a zero tolerance. The purpose of this discussion was to show the trend of thought and also the opinions toward a subject that is packed with "dynamite."

The discussions officially ended with the sound of the dinner gong on Saturday evening, after which the "Spec Taters," little and big, enjoyed bridge, dancing, music and singing around the big fire place of the summer camp parlor. Here many talents were brought to light as one after another prosaic potato worker volunteered to amuse the astonished onlookers by his "peeling" forth of melodious musical strains.

The next meeting place will be in Nebraska one year from date with Mr. Marx Koehnke elected as Chairman.

Those attending, together with their addresses and titles, are as follows: M. F. Babb (Physiology), Cheyenne, Wyo.; Earl Barrios (Potato Certification), Watertown, S. Dak.; H. W. Benn (Agri. Agent Union Pacific Railroad), Omaha, Nebr.; E. R. Bennett (Plant Pathology), Boise, Idaho; A. M. Binkley (Horticulture), Fort Collins, Colo.; W. P. Bohn (Pathology), Cheyenne, Wyo.; W. F. Buckholtz (Plant Pathology), Brookings, S. Dak.; D. H. Dewey (Physiology), Cheyenne, Wyo.; L. W. Durrell (Botany & Pathology), Fort Collins, Colo.; T. P. Dykstra (Pathology, U. S. D. A.), Beltsville, Md.; A. D. Edgar (Agricultural Engineering), Scottsbluff, Nebr.; W. C. Edmundson (Potato Breeding), U. S. D. A., Greeley, Colo.; W. T. Edmundson, Greeley, Colo.; L. C. Erickson (Seed Analysis), Laramie, Wyo.; M. W. Felton (Pathology), Lincoln, Nebr.; B. R. Ferguson (Horticulture Am. Refrigerator Transit), Monte Vista, Colo,; E. A. Fletcher (Grower, Pres. S. Dak. Potato Growers), Garden City, S. Dak.; D. P. Glick (Bacteriology), Fort Collins, Colo.; R. W. Goss (Pathology), Lincoln, Nebr.; F. M. Harrington (Horticulture), Bozeman, Mont.; W. J. Henderson (Ext. Plant Pathology), Fort Collins, Colo.; J. A. Hill (Dean & Director, Agr. Exp. Station), Laramie, Wyo.; R. E. Hill (Entomologist), Lincoln, Nebr.; Marx Koehnke (Potato Certification), Alliance, Nebr.; F. A. Krantz (Potato Breeding), St. Paul, Minn.; James E. Kraus (Physiology), Aberdeen, Idaho; W. A. Kreutzer (Pathology), Fort Collins, Colo.; George M. List (Entomology), Fort Collins, Colo.; J. E. Livingston (Pathology), Lincoln, Nebr.; R. H. McFarland (Commissioner of Agriculture), Cheyenne, Wyo.; W. F. McGee (Potato Certification), Fort Collins, Colo.; J. G. McLean (Potato Certification), Fort Collins, Colo.; Ralph Manuel (Potato Certification), Fort Collins, Colo.; C. H. Metzger (Potato Specialist), Colorado Springs, Colo.; John Noonan (Secretary S. Dak. Potato Growers' Assoc.), Watertown, S. Dak.; J. M. Raeder (Pathology) Moscow, Idaho; W. A. Riedl (Potato Breeding), Laramie, Wyo.; Don Ritter (Crops, Extension), Laramie, Wyo.; L. A. Schaal (Pathology, U. S. D. A.), Greeley, Colo.; Arden F. Sherf (Pathology), Lincoln, Nebr.; B. Thomas Snipes (State Entomologist), Powell, Wyo.; J. R. Sprengle (County Agent), Steamboat Springs, Colo.; G. H. Starr (Pathology), Laramie, Wyo.; J. L. Toevs (Supt. Experiment Station), Aberdeen, Idaho; A. F. Vass (Agricultural Economics), Laramie, Wyo.; R. L. Wallis (Potato Psyllid Investigations, U. S. D. A.), Scottsbluff, Nebr.; Dave Wasden (Farming), Cody, Wyo.; H. O. Werner (Horticulture), Lincoln, Nebr.; and T. R. Wright (Pathology), Boise, Idaho.

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THE COMPARATIVE BORON CONTENT OF POTATO LEAVES AND TUBERS PRODUCED UNDER DIFFERENT CULTURAL CONDITIONS[1]

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In the course of a series of investigations being conducted at the Wisconsin Agricultural Experiment Station regarding the relations between the mineral nutrition of the potato plant and the cooking quality and physiological responses of the tuber, it became of interest to determine the value of tuber analyses as an indication of the nutritional status of the entire plant. Although previous workers (4) had shown that there may be some correlation between the composition of the tubers and fertilizer treatment, the question of whether or not this correlation was extensive and consistent enough to validate conclusions drawn from tuber analyses alone had not been satisfactorily dealt with.

The element boron was selected for this study for several reasons. First, because this element is becoming a critical one in many soils; in fact Truog and coworkers (7) have estimated that as much as 25 per cent of the cultivated land in this state is seriously depleted. Second, the fact that the boron requirement lies midway between that of the major nutrient elements and those needed in so-called "catalytic

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[2]Wisconsin Alumni Research Foundation Fellow in Biochemistry, Assoc. Professor of Biochemistry, and Assoc. Professor of Genetics, Horticulture and Plant Pathology, respectively.

amount", and the further observation that it is apparently needed throughout the life of the plant (8) would make the results obtained of more general significance than those pertaining to other minor plant nutrients. Moreover, although a few analyses are recorded in the literature (5), no extensive survey of the normal content of this element in the leaves and tubers of the potato has been made; we have, therefore, begun to accumulate such data as pertinent in our study of the biochemical role of boron in the plant.

MATERIALS AND PREPARATION OF SAMPLES

The leaf and stem samples were obtained from the adaptation plots of the University's potato improvement program located at Almond in Waushara county on the Waukesha sandy loam, at Antigo, in Langlade county on the Antigo silt loam; and at Starks, in Oneida county on the Vilas sandy loam. These locations are progressively further north on soils of somewhat dissimilar character. The leaf and stem sampling was done at the three locations on successive days from the 11th to the 13th of July, 1940. The leaf blades were immediately detached from the stem, dried, ground to pass an 80-mesh sieve and bottled for later analysis. The tuber samples were taken, after the normal maturation period and stored for approximately 50 days in a refrigerated cellar at 42-44° F. (*i.e.,* simulation of the conditions which would normally obtain in taking samples for tuber analysis). Twenty-five medium-sized tubers from graded lots corresponding to the leaf and stem samples were washed in distilled water with gentle scrubbing. Each tuber was cut in half longitudinally and one-half cut in thin slices by a slicing machine. These were spread on trays, heated rapidly in a steam oven to approximately 90° C. and then placed in a drying oven with a continuous passage of air at 65° C. until thoroughly dry. The dry material was then ground to pass a 100-mesh sieve and stored.

METHODS

Ash:—The oven-dried sample was ashed at 500° C. in a thermostatically controlled muffle according to the procedure of the A. O. A. C.

Boron:—The colorimetric procedure of Carson *et al* (2) and Berger and Truog (1) was modified in several respects and adapted to the Evelyn photoelectric colorimeter. The ashed sample was thoroughly triturated with such quantities of 0.36 N sulfuric acid that each ml. aliquot would contain from 2 to 6 micrograms of boron; it was

found that very thorough trituration and standing in the cold was necessary to remove the major portion of the boron in the ash. A 1 ml. aliquot was then accurately measured into a carefully standardized Evelyn colorimeter tube; in some cases filtration through cotton wrapped around the tip of the pipette was necessary to produce a clear extract. Ten ml. of 98.5 per cent sulfuric acid containing 0.015 mg. of quinalizarin per ml. was then added from a closed-system burette and the mixture allowed to stand for at least three hours before being read in the

TABLE 1.—*Regional variations in boron and ash content of actively functioning leaves and stems and mature tubers of potatoes grown in Wisconsin in* 1940

	Leaf		Stem		Tuber	
	Ash[2]	Boron[3]	Ash	Boron	Ash	Boron
Almond						
Triumph[1]	21.1	73.8	24.5	30.0	5.8	9.4
Cobbler	18.8	70.1	22.0	37.1	5.8	10.3
Chippewa	22.0	40.2	22.6	31.6	6.3	11.8
Sebago	17.3	44.6	22.5	40.3	6.4	13.9
Rural	17.0	43.2	26.8	66.6	5.4	6.5
Russet Rural	17.5	51.8	24.5	38.3	5.7	12.6
	19.0	53.9	23.8	40.7	5.9	10.8
Antigo						
Triumph	21.9	49.4	31.1	31.6	6.2	10.0
Cobbler	18.9	35.0	27.8	34.9	5.1	8.6
Chippewa	20.1	32.5	28.5	31.6	5.1	8.9
Sebago	20.9	36.5	28.9	34.6	6.2	10.1
Rural	20.4	32.5	26.9	36.9	6.5	10.1
Russet Rural	20.4	35.5	30.0	35.3	5.9	9.3
	20.5	37.2	28.9	34.1	5.9	9.5
Starks						
Triumph	17.2	26.5	28.9	28.1	4.4	8.8
Cobbler	17.5	23.6	23.9	23.6	5.1	5.5
Chippewa	17.7	28.7	25.6	27.6	5.1	8.5
Sebago	17.8	26.7	25.3	19.0	4.2	8.2
Rural	17.9	28.8	24.5	24.3	4.0	9.5
Russet Rural	18.9	20.9	35.5	26.4	4.1	7.0
	17.8	25.5	25.6	24.8	4.5	7.9

[1]Arranged in approximate order of maturity.
[2]In per cent on a moisture-free basis.
[3]In micrograms per gram on a moisture-free basis.

colorimeter. Various workers have reported (1,6) no color change after 30 minutes but our experience has been that the reaction is not completed in that length of time. We have also observed that concentrations of quinalizarin from three to five times that suggested by Feigl and Krumholz (3) and used by Berger and Truog for visual determination of boron (1) are more satisfactory for the quantitative photocolorimetric estimation of boron. The absorption curve approximates Beer's law over a wider concentration of boron and greater galvanometer deflections are obtained with equal increments of boron when greater dye concentrations are employed. The amounts of boron present in the sample were obtained by use of a standard curve prepared with known quantities of boric acid.

Discussion

The data of ash content show no consistent relations between varieties at the different locations. Therefore there appear to be no differences between the early and late varieties in this respect. On the whole, the ash contents of leaf and stem are greater in the plants produced at Antigo on the clay loam as compared with the plants produced on the lighter soils. This fraction of the tubers, however, was greater at both Almond and Antigo than at Starks. No correlation appears between the ash content of the different organs of the plant of a single variety of potato at a single location. The analytical results of one variety are not universally either greater or less than those of another produced under the same cultural and climatic conditions.

There is, likewise, no consistent difference between varieties regarding the boron content at the different locations. Like the total ash, however, this constituent was more abundant in the leaf and stems of crops sampled at Antigo and Almond than those sampled at Starks. This same relationship also extended to the tuber, but less definitely and consistently so than for the other organs.

No correlation appears in a comparison of the relative contents of ash and boron from organ to organ in the various samples. Thus, in several instances the tubers of plants having a high boron content of the leaf at the time of sampling are below average with respect to tubers of other varieties grown at the same location.

It is recognized that the limited samplings here examined and the hazards of contamination of the plant tissue by soil and spraying preclude the formulation of final conclusions. It does seem clear, however. that tuber analyses disclose little information regarding variations in

total ash or boron content (and possibly abnormalities with respect to other elements as well) which may occur in the leaf or stem.

There does appear to be a relation between the location and the boron content, but since only inadequate soil samples were taken it is not yet clear whether this response is caused by varying amounts of available boron in the soil or to some other factor or combination of factors. This problem is being pursued further in more extensive field trials.

CONCLUSIONS

Analyses of the potato tuber without corresponding leaf and stem samples give little pertinent information regarding the total ash content or the status of boron nutrition of the plant as a whole. Boron analyses of several varieties of potatoes produced in three regions of Wisconsin under similar cultural treatment have shown the following ranges and averages in micrograms per gram of dry tissue for different parts of the plants: Leaf 20.9-73.8, 38.9; stem 19.0-66.6, 32.2; and tuber 5.5-13.9, 9.2.

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THREE YEARS OF POTATO SPRAYING IN SOUTHEASTERN WISCONSIN

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Introduction

Spraying of potatoes with Bordeaux mixture is a widely accepted practice in southeastern Wisconsin. Experiments conducted over a 3-year period (1937-1939) were designed to determine: (1) the effect of varying the seasonal distribution of copper sulphate and lime in Bordeaux mixture; (2) the best copper-lime ratio; and (3) the comparative value of several formulae of Bordeaux mixture and certain proprietary copper compounds. The efficiency of each treatment in the control of insects and diseases was recorded, yield being used as the main basis of comparison.

Methods and Materials

The experiments were carried out each year on the same farm and in a portion of a large field of Irish Cobbler potatoes. The soil was a Carrington silt loam with a reaction about pH 6.5. Single-row plots, 2 rods long, were arranged at random in each of 3 replicate blocks in 1937 and 1938 and in 4 replicate blocks in 1939. Sprays were applied at 200 pounds pressure per square inch and approximately 145 gallons per acre with a single-nozzle gun in a manner comparable to that of a 3-nozzle-per-row boom. This amount applied was somewhat higher than that used commercially in this area, but it was the minimum necessary to obtain good coverage with the equipment employed. It was observed that a power-driven machine operating at 400-pounds pressure and 120 gallons per acre in another part of the same field provided equally good coverage. Many of the commercial sprayers in this section are of the old traction-driven type and do not develop over 200 pounds pressure. The experimental applications were considered comparable to those made by the old-type machines. The spray was applied on quiet days to avoid the blowing of material to adjacent rows.

Bordeaux mixture was made up according to different formulae from previously prepared stock solutions of copper sulphate and hydrated lime. The proprietary copper sprays were weighed and mixed

into a paste before diluting. In 1937 and 1938 talc was added to the last-named sprays to give a residual effect on the plant comparable to that of lime in 5-5-50 Bordeaux. Commercial spreaders and stickers were used with the proprietary copper sprays in accord with recommendations of the manufacturer. Calcium arsenate, 2 pounds to 50 gallons, was added to the spray when necessary to control Colorado potato beetle and potato flea beetle.

There was sufficient rain in May, June, and July each year to promote good plant growth, but August of 1937 and 1939 was too dry for best development, while 1938 was a cool moist season throughout. Foliage diseases were not important. Early blight (*Macrosporium solani*, E. & M.) and late blight (*Phytophthora infestans* (Mont.) De By.) developed on only a few unsprayed plants in 1938. Each year there was a moderate to severe infestation of potato leaf hopper (*Empoasca fabae*) mostly on the unsprayed plants. This was the primary cause of tipburn, which increased as the season advanced.

The first spray was applied when the plants were 4 to 8 inches tall and successive applications were made at approximately 10-day intervals. A total of 6 applications was made in each season.

The tipburn and growth readings were taken at the time of each application. The difference in vine growth was estimated by comparison between treatments, and the percentage of affected leaves was obtained by making random counts. These data served as a basis of evaluating each treatment at a particular period but were not wholly comparable to those of another period or season.

Experimental Results

The effect of varying the seasonal distribution of copper sulfate and lime in Bordeaux mixture

Mader and Blodgett (2) reported increased yields from Russet Rural potatoes when heavy applications of copper were made early in the season. This was also correlated with an increase in the number of leaves and total weight. In these studies, treatments 4 to 10 inclusive (table 1) received varying amounts of copper sulfate and lime throughout the season. Treatment 4 received a high concentration at the beginning of the season and its strength was reduced with each subsequent application. Treatment 5 was the converse of 4, receiving a low concentration at the start and finishing with 12-12-50. Treatment 6 was similar to 1 except that a low lime-to-copper ratio was

followed throughout the season. Since some evidence was obtained that a high concentration of lime applied late in the season reduced the amount of tipburn, treatment 7 was designed to give a high concentration of copper early in the season with a low-lime ratio. As the season advanced the lime ratio was increased to give a high lime-to-copper ratio. Treatment 8 was the reverse of 7. Treatments 9 and 10 were also opposite each other in seasonal distribution of copper and lime but differed from other treatments mentioned in that a higher concentration was maintained throughout the season. The total amount of metallic copper applied per acre during any one season is given in the table.

Treatments 4 to 10 showed more vine growth and much less tipburn than did the unsprayed plots during the 3 seasons. The difference between rows treated with high concentration of copper sulfate early in the season (treatments 4, 6, 7, 9) and those of either a low concentration (treatments 5, 8, 10) or a straight 5-5-50 Bordeaux (treatment 1) was less apparent. In 1937 the first tipburn appeared at the time of the second spray on the untreated rows but no appreciable amount of tipburn developed on treatments 4 to 10 until the time of the fourth spray. When the 6th and last application was made, no difference was apparent in vine growth between the various Bordeaux formulae, and leaf counts showed no significant variation in number of affected leaves, whereas more than 50 per cent of the plants in the untreated rows were dead and the remainder showed severe tipburn. Tipburn did not appear in 1938 until the time of the 4th application and did not become very evident on treatments 4 to 10 until the 6th and last spray. At this time treatments 4, 7, 9, 10 showed slightly more vine growth and less tipburn than treatments 5, 6, 8, and 1. With the exception of treatment 6 those rows receiving higher concentrations early in the season seemed to have slightly more vine growth and less tipburn. In 1939 no appreciable amount of tipburn was evident until the 4th spray. Final counts taken at the time of the last spray showed that treatments 7, 8, 9, 10 and 1 had the least amount of leaf injury and possibly the best vine growth. These experiments did not show a correlation between seasonal distribution of copper and the general appearance of the vines or the amount of tipburn.

The yields of the rows receiving treatments 1 and 4 to 10 were significantly greater than those of the untreated rows in 1937 and 1939, but there was no significant difference between the spray treatments.

Effects of different copper-lime ratios

Mader and Blodgett (2) also showed that under New York conditions increased yields were obtained by lowering the lime content

of Bordeaux mixture, and that smaller amounts of copper were required to give maximum yields. In the experiments reported here a low (treatment 2) and a high (treatment 3) lime-to-copper ratio were compared with the standard 5-5-50 Bordeaux mixture (treatment 1). All treatments showed more vine growth and less tipburn than the checks. In all 3 seasons, treatment 2, having the low lime concentration, showed less vine growth and more tipburn than did the 5-5-50 formula, whereas treatment 3 appeared equal to the latter in freedom from tipburn and in size of plants. In 1937 and 1938, treatment 2 matured earlier than either treatment 1 or 3, but this difference was less evident in 1939. There was no significant difference in total yields between either the high- or low-lime formula and the standard 5-5-50.

Efficiency of four proprietary copper compounds compared with Bordeaux mixture

The efficiency of four types of fixed copper compounds was compared with Bordeaux mixture during 1 or more seasons from 1937 to 1939. These proprietary materials and the respective percentages of metallic copper in them were: copper oxychloride, 45 to 47; yellow cuprous oxide, 45; tribasic copper sulfate, 34; and neutral copper hydroxide, 24. In 1937 and 1938 treatments 11 and 13 (table 1) were applied at the rate of 1½ pounds to 50 gallons of water; in 1939 all proprietary materials (treatments 11 to 18) were used at 1½ and 3 pounds per 50 gallons of water, respectively. At the former concentration the total amount of metallic copper applied per season (treatments 11, 13, 15 and 17) was lower than that applied with standard (5-5-50) Bordeaux (treatment 1); at the latter concentration (treatments 12 and 14) the total amount of metallic copper was greater than that of standard Bordeaux. Treatments 16 and 18 contained less copper than standard Bordeaux.

Early in the season, rows sprayed with fixed copper compounds appeared equal to those with Bordeaux in freedom from tipburn and in amount of vine growth. After the fifth or sixth application, however, the former began to show more tipburn, growth slowed rapidly, and the plants matured from 1 to 2 weeks earlier than those sprayed with Bordeaux. Correspondingly, the low-concentration treatments (11, 13, 15, and 17) showed more tipburn and matured earlier in 1939 than the high-concentration ones (treatments 12, 14, and 16). Treatment 18, which was also applied at the rate of 3 pounds to 50 gallons of water, showed more injury than treatments 12, 14, and 16, but the total amount of metallic copper was only one-half that of treatments 12 and 14 and 3 pounds less than in treatment 16. If the material in treatment 18 had

been used at the same metallic copper concentration as in treatments 12 and 14, it might have given better tipburn control.

Copper oxychloride (treatment 11) tested over a 3-year period at 1½ to 50 concentration showed a significant increase in yield compared with the unsprayed plots for that period. In 1937, the yield for this treatment was equal to that of standard Bordeaux, but in 1939 it was somewhat lower. However, when the concentration was doubled (treatment 12) the yield was nearly equal to that of the standard Bordeaux. In 1938, neither the fixed copper nor Bordeaux sprays showed a significant increase in yield over the untreated. Yellow cuprous oxide tested in 1937 and in 1939 at 1½ to 50 (treatment 13) gave small but consistent increases for the 2-year period. When the concentration was doubled (treatment 14), the yield was comparable to the standard Bordeaux in 1939. The other 2 proprietary compounds were tested only during 1939. Tribasic copper sulfate at both concentrations (treatments 15 and 16) gave statistically significant increased yields compared with the unsprayed plots, and at the higher concentration it was nearly as good as Bordeaux. Neutral copper hydroxide (treatments 17 and 18) did not give significantly better yields than the untreated plots at either concentration.

Discussion of Results

Results of experiments conducted over a period of 3 years in southeastern Wisconsin showed increased yields from spraying potatoes of the Irish Cobbler variety. Even greater differences might have occurred had leaf-blight diseases been prevalent. Tipburn was moderately severe each year, and its reduction was correlated inversely with increase in yield in 1937 and 1939 but not in 1938. The relatively cool, wet season in that year produced a rank and succulent vine growth even on the unsprayed plots, and the average yield for all plots was about 200 bushels more per acre than for either of the other 2 years. As for moisture and temperature, the 1938 season was similar to potato-growing areas in Maine where little benefit from spraying other than that of disease control is obtained (1). The two dry seasons of 1937 and 1939 are typical of the environmental conditions in western New York described by Mader and Blodgett (2) in which they obtained increased yields from spraying when diseases were of minor importance. From these experiments it can not be ascertained whether increased yields in 1937 and 1939 from spraying were largely due to control of tipburn or to some other effect which the spray exerted on

TABLE 1.—*Comparative yields for a 3-year period from Irish Cobbler potatoes sprayed with various formulae of Bordeaux mixture and with fixed copper compounds*

Treatment No.	Material Used	Concentration Used at Application Indicated: 1st	2nd	3rd	4th	5th	6th	Total Metallic Copper	Average Yield (Bushels per Acre): 1937	1938	1939
								Lbs. per Acre			
1	Bordeaux	5-5-50 for all applications						21.7	277	503	242
2	"	5-2½-50 " "						21.7	284	432	242
3	"	5-7½-50 " "						21.7	290	459	246
4	"	12-12-50	9-9-50	6-6-50	4-4-50	2-2-50	1-1-50	25.2	295	531	233
5	"	1-1-50	2-2-50	4-4-50	6-6-50	9-9-50	12-12-50	25.2	305	481	239
6	"	10-5-50	8-4-50	6-3-50	4-2-50	3-3½-50	2-1-50	24.2	270	472	243
7	"	10-5-50	8-4-50	5-5-50	5-7½-50	3-6-50	2-4-50	24.2	293	476	245
8	"	2-4-50	3-6-50	5-7½-50	5-5-50	8-4-50	10-5-50	24.2	281	493	246
9	"	12-6-50	10-6-50	8-8-50	6-10-50	5-10-50	4-12-50	33.0	...	477	234
10	"	6-12-50	6-10-50	8-8-50	10-6-50	10-5-50	12-4-50	38.0	...	456	251
11	Copper oxychloride	1½-50 for all applications						13.8	272	478	212
12	" "	3-50 " " "						27.6	...	...	230
13	Yellow cuprous oxide	1½-50 " " "						13.8	225		192
14	" "	3-50 " " "						27.6	...	...	235
15	Tribasic copper sulfate	1½-50 " " "						8.6	...	...	212
16	" "	3-50 for all applications						17.2	...	...	237
17	Neutral copper hydroxide	1½-50 " " "						6.8	...	...	207
18	" "	3-50 " " "						13.6	...	...	209
19	None							0	177	433	175
Difference required for significance (19:1)										50	31

the plant. It does demonstrate, however, that spraying may be expected to increase yields in relatively dry years when leaf diseases are not a factor, but in cool, wet years this response is less evident, unless leaf blights appear early and become destructive.

All Bordeaux treatments showed an average increase from 40 to 60 bushels per acre as compared with the untreated plots (table 1, column 11), but there was no significant difference between treatments for the 3-year period. Schedules arranged to apply most of the copper early did not give higher yields than those whereby most of the copper was applied late or uniformly throughout the season. Even if the total amount of copper applied per season had been reduced either by a lower concentration or a small amount of solution applied, a change in the effect of varying the distribution of copper throughout the season does not seem likely since only enough material was used to obtain good coverage at 200-pounds pressure. No difference between treatments in the stimulation of growth was evident at any time until after the fourth or fifth application. The 3 seasons' results indicate that unequal distribution of copper has no advantage over standard 5-5-50 Bordeaux, for this early variety in southeastern Wisconsin.

Experiments with different copper-lime ratios also failed to give increased yields in comparison with standard Bordeaux mixture. The 5-2½-50 formula gave poorer control of tipburn, but this was not reflected in total yields. Other formulae combining unequal distribution of copper and lime through the season with a low lime-to-copper ratio also failed to show consistent differences in yield. Neither treatment 9, which at the beginning of the season had a higher copper-to-lime ratio and was changed with each subsequent application to have a higher lime-to-copper, nor its opposite (treatment 10) was better than standard Bordeaux in yield. Since the higher amounts of lime appeared to give better tipburn control, it does not seem advisable to use the lower lime-to-copper ratio.

Tests conducted with 4 proprietary compounds have shown that 3 of these may increase yields when leaf-blight diseases are not a factor. Copper oxychloride and yellow cuprous oxide tested 3 and 2 years, respectively, gave significantly better yields than the unsprayed plots. Tribasic copper sulfate tested only in 1939 also gave increased yields. Neutral copper hydroxide failed to increase yields, but at the concentrations used the per cent of metallic copper was lower than in the other materials. The 1939 results indicate that higher concentrations than are usually recommended by the manufacturer are necessary to give maximum yields. Copper oxychloride, yellow cuprous oxide and

tribasic copper sulfate when used at concentrations of 3 pounds to 50 gallons of water gave increased yields not significantly different than standard Bordeaux in 1939. All plants sprayed with the fixed copper usually ripened from 4 to 10 days earlier than the Bordeaux plots.

For the commercial grower of Irish Cobbler in southeastern Wisconsin 5-5-50 Bordeaux mixture is equal to or better than any of the other Bordeaux formulae or fixed copper compounds tested, in increasing yields. The proprietary copper compounds, however, may be used wisely by the small grower or the home gardener since they may be more convenient to make up and apply.

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EFFECT OF DAY LENGTH UPON THE VEGETATIVE GROWTH, MATURITY, AND TUBER CHARACTERS OF THE IRISH POTATO

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INTRODUCTION

Since 1935 when the breeding program was begun in Louisiana, it has been observed that all seedling plants when grown to maturity in the fall set tubers. Also it has been observed that a large percentage of these fall-grown potatoes resulting from seedling plants were smooth as compared with spring-grown potatoes from the same seedlings. With most family lines, when grown during the spring not more than 50 per cent of the potatoes were smooth and with some lines as many as 25 per cent of the spring-grown plants did not produce any potatoes although the plants were extremely vegetative.

The temperature and photoperiod of the two seasons, spring and fall, are as follows: under fall conditions the temperature advances from warm to cool and the photoperiod decreases from a 14-hour day to a 10-hour day; in the spring the temperature advances from cool to warm and the photoperiod from a 11½-hour day to a 14-hour day. Of

the two environmental factors, temperature and day length, it seemed that day length exercised the major influence.

In the spring of 1939 an experiment was set up to determine what effects different length photoperiods would have upon the vegetative growth, maturity, and tuber characters of the Irish potato.

Method of Procedure

In order to study the photoperiod effects, four treatments were set up as follows: Treatment 1-18 hours; treatment 2-8 hours; treatment 3-12 hours; and treatment 4-normal day length. In order to arrange for photoperiod controls, cold frames were constructed. The cold frames were built to a height of about three feet in the back and two feet in the front. Partitions were made so that the frame was divided into four sections, each section measuring six by six feet.

Day length was supplemented by suspending one 300-watt bulb about four feet above the plants in the frame receiving extra light. In treatments 2 and 3, where the day lengths were shorter than normal, the frames were covered with two layers of black satin cloth to regulate the day length. The cloth was rolled down over the frames in the afternoon at the proper times to regulate day length as desired. Electric fans were set up in treatments 2 and 3 to bring in outside air and maintain the normal outside air temperature as nearly as was possible.

In each of the four frames three varieties were planted on the 10th of February:

(1) Mexican Seedling No. 8, which is considered a short-day plant;
(2) K-1 selfed Katahdin. This variety is extremely early and is considered a long-day plant;
(3) T 3-1—Selfed Triumph, a short-day plant.

In planting these three varieties in the four treatments the plantings were made in a randomized design. All plants were given the same cultural treatments throughout the growing period. All plots were harvested on the 7th of June.

Experimental Results

Treatment 1. All plants in this treatment showed extreme vegetative growth. The Mexican Seedling No. 8 and T 3-1 were indeterminate in vegetative growth, making vines from five to six feet in length. The plants were still growing at harvest time and had produced as many as three or more crops of blossoms. All plants pro-

duced a heavy set of seed balls. This treatment produced a higher yield than treatment 2, although the tubers were rough and irregular except those of the K-1, which although it made a heavy vegetative growth, was not indeterminate in its growth habits.

Treatment 2. Plants in this treatment which were given eight hours of day length, showed less vegetative growth than plants in any of the other treatments: K-1 reached an average height of 12 inches; the T 3-1, 18 inches; and the Mexican Seedling No. 8, 22 inches. These plants also matured first, between the 15th and the 20th of May. The K-1 reached maturity first; the T 3-1 second; and the Mexican Seedling No. 8 was last. The plants were considered mature when they had died to the ground level. In this treatment none of the plants of the three varieties blossomed. The tubers of all three varieties were smoother and the eyes more shallow than those in any of the other treatments, although the yield was the lowest obtained. The T 3-1 and the Mexican Seedling No. 8 were very smooth as compared with the normal appearance of these two seedlings when grown in the field in Louisiana.

Treatment 3. Throughout the period of this experiment a constant 12-hour day was maintained. The plants in this test were the second in order of maturity, which occurred between the 20th and the 25th of May. Again K-1 was first to mature, followed by the T 3-1 and Mexican Seedling No. 8. No blossoming occurred on any of the plants in this treatment. All the tubers from the three varieties were smooth, approaching very closely the smoothness that resulted from treatment 2.

Treatment 4. This was considered as a check and was allowed normal day length. During this experiment the day length advanced from 11½ hours in March to 14 hours in June at the time of maturity. In this controlled treatment many of the plants at harvest time still showed some vegetative growth. The plants of K-1 matured about the 25th of May; however, at harvest time some plants of T 3-1 were still living, showing green stems, whereas all of the Mexican Seedling No. 8 plants were still green. The Mexican Seedling No. 8 blossomed and set seed freely and some blooming and seed setting occurred on the T 3-1. There were a few flowers but no seed set on the K-1. The tubers of the Mexican Seedling No. 8 and T 3-1 were rough and had deep eyes; however, those of the K-1 remained smooth.

This experiment has borne out previous observations that photoperiod has a very definite effect upon the vegetative growth, maturity, and tuber characters. In reference to tubers, the length of day influences very definitely the yield and the smoothness of the potatoes, par-

ticularly with reference to depth of eyes. Both heredity and environment play an important part in the smoothness or roughness of the potatoes. It is the modification of some of the hereditary characters by environment that the authors wish to point out in this paper. To further illustrate this the following data are presented on segregations from six different lots of seedlings for long and short-day plants. Of these lots two were selfed lines and four were lines consisting of different crosses between T 3-1, which is a selfed Triumph, and Katahdin, Chippewa, Cobbler, and K-1. Also data on selfed lines of T 3-1 and Chippewa are presented.

TABLE 1.—*Short and long-day segregates from first spring-grown crop.*

Variety	No. Plants	No. Segregates for	
		Long Day	Short Day
T 3-1	29	11	18
C x T 3-1	83	46	37
Ch x T 3-1	124	94	30
K-1 x T 3-1	25	14	11
Chippewa	71	51	20

In this experiment, Katahdin, Chippewa, Cobbler, K-1, and Chippewa selfed are classed as long-day plants. With the exception of the Louisiana K-1 these plants were selected in the North under long-day conditions. The T 3-1 is a segregate from Triumph selfed and is considered a short-day plant. When grown under short-day conditions the potatoes are satisfactorily smooth but when grown under long-day conditions the potatoes are rough and plants very vegetative. It will be noted that when early-maturing varieties, that is, long-day varieties, are crossed with T 3-1, a short-day variety, a higher percentage of the segregates belong to the long-day, or earlier-maturing, class. From a selfed line of T 3-1 it will be noted that more of the segregates fall into the short-day class whereas with the Chippewa, an early-maturing variety, a higher percentage of the segregates fall into the long-day, or early-maturing, class.

Discussion

The results obtained with fall- and spring-grown potatoes and from the light experiments discussed in this paper might help to explain the variations noted in varieties of potatoes which have been moved from one section of the world to another where the photoperiods of the localities are widely different. To further illustrate this, very few European varieties have proved satisfactory in the United States. At the same time very few varieties have proved satisfactory when moved to this country from the high altitude equatorial areas of South America. When introducing the northern European varieties into the United States, one would expect them to show a lower yield than native varieties and when varieties are brought from the equatorial areas one would expect them to be excessively vegetative and produce very few potatoes. The potatoes produced would be unusually rough. The same thing would apply in this country when northern-grown varieties are shipped into the south for potato production, the result being lower yields than in the area where the original selection was made. Under the short-day conditions of the south the potatoes mature earlier resulting in lower yields, although the potatoes are probably smoother than when the same varieties are grown under long-day conditions. On the other hand, if the selection is made in the South for high yielding ability, it might be that when the potato is increased in the north, the tubers would have deeper eyes and a rougher appearance than when grown in the south.

Summary

1. Studies concerning the effect of length of day were made on vegetative growth, maturity, and yield and smoothness of tubers of the Irish potato when grown under field and controlled conditions.

2. With field and controlled experiments, plantings under short days showed less vegetative growth, matured earlier, and the potatoes were generally smoother. The opposite effects were obtained under long-day conditions; the plants were very vegetative, matured later, tubers had deeper eyes, and were more irregular in shape, although, the total yields were higher.

3. Seedlings representing several family lines were studied and the resulting segregations could be classified as either long or short-day plants. The parental combinations had a marked influence on whether the resulting seedlings would fall into the long or short-day group.

THE EFFECTS OF CERTAIN ENVIRONMENTAL FACTORS ON TUBERIZATION IN THE WILD POTATO, *SOLANUM COMMERSONII*[1]

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Studies on the climatic and soil conditions have done much to increase the yield of potato tubers. Very few investigations have considered tuberization in terms of a specific entity not wholly dependent on carbohydrate formation for its fulfillment. The present paper is a report of the first in a series of experiments designed to determine, if possible, the factors which affect tuber formation.

Table 1.—*Experimental outline of treatments*

Day Period		Day Temperature		Dark Period	Dark Temperature	
Short	10 hrs.	High	77°F.	16 hrs.	High	77°F.
"	" "	"	77°F.	16 "	Low	56°F.
"	" "	Low	56°F.	16 "	High	77°F.
"	" "	"	56°F.	16 "	Low	56°F.
Long	16 hrs.	High	77°F.	10 "	High	77°F.
"	" "	"	77°F.	10 "	Low	56°F.
"	" "	Low	56°F.	10 "	High	77°F.
"	" "	"	56°F.	10 "	Low	56°F.

Experimental

Plants of *S. commersonii,* from seed planted November 7, 1939. were placed under the treatments outlined in table 1. Regarding the use of the terms "long" and "short" day and "high" and "low" temperature, table 1 is explanatory. To obtain a long day the normal daylight hours were supplemented by 100 Watt Mazda lights. The average temperatures in the high and low temperature houses for the duration of the experiment were 77° F. and 56° F. respectively.

The treatments involved all the possible combinations of the two-day lengths and the two day and night temperatures studied. Eight plants were grown in each of the eight treatments and were shifted at

[1]Presented as Paper No. 233, Department of Vegetable Crops, Cornell University, Ithaca, New York.

the proper time to obtain the changes where day and night temperatures differed.

Results

Factorial analysis was applied to the data to determine significance of the treatments on the fresh weight of tubers, stolons and the ratios of tubers and stolons to the top weight. The results of treatment effects which were significant will be the only ones considered in this report.

Tuber yields: All the treatment effects except the interaction of day length and night temperature significantly affected the yield of tubers.

Tuberization measured by mean tuber yield per plant (table 2) was promoted by a short-day, high day temperature and high night temperature.

Table 2.—*Mean tuber yield per plant of significant main effects.*

Day Length	Weight	Day Temperature	Weight	Night Temperature	Weight
	Gms.		Gms.		Gms.
Long	3.4	High	13.6	High	18.7
Short	15.3	Low	5.0	Low	8.0

The beneficial effect of short days on tuberization was amplified by high day temperature. Under long days the effect of temperature was such that a high day temperature was probably no better than low day temperature and neither temperature in long days resulted in yields as good as plants exposed to short days.

Day temperature and night temperature interacted to effect tuber yield as follows: a high day temperature was beneficial only when the night temperature was also high. Shifting the plants from a high day temperature to a low night temperature was actually deleterious to tuber yield. A high day temperature, to be effective, must be accompanied by a high night temperature. When the day and night temperatures were low, the yield was better than when the plants were shifted from high day to low night temperature. In fact a high night temperature seemed to have a more promotive influence on tuberization than a high day temperature.

The effect of day temperature, day length and night temperature interacting was that a low night temperature reduced the tendency for a high day temperature to amplify tuberization in short days.

Tuberization, therefore, is apparently a short day process which is benefited by day and night temperatures of 77° F. and reduced by day and night temperatures of 56° F., regardless of whether the temperatures are considered singly or in combination.

Stolon yields: All the treatments considered were significant in their affect on stolon production.

Compared with the mean tuber yield the effect of day length was reversed and the effect of day and night temperature was the same on mean stolon yield per plant. A larger yield of stolons (table 3) was produced under the long-day treatment and under the high day and high night temperature levels.

The better stolon development under long days was increased by high day temperature and also by high night temperature levels. In this case a high night temperature was more beneficial than a high day temperature.

TABLE 3.—*Mean stolon yields per plant of significant main effects*

Day Length	Weight	Day Temperature	Weight	Night Temperature	Weight
	Gms.		Gms.		Gms.
Long	17.9	High	18.8	High	19.2
Short	7.3	Low	6.4	Low	6.0

Day temperature and night temperature effects interacted to promote most stolon growth when both were high, and least when the night temperature was low regardless of the day temperature level. In connection with this low night temperature effect it may be that the average night temperature of 56° F. was low enough to be a limiting factor in the yield of tubers or stolons. However, until other temperature levels are studied it would be unwise to make such an assumption.

From the significant interaction of the three factors it may be concluded that a warm night temperature amplified the tendency for a warm day temperature to increase the efficacy of long days in producing stolons.

The ratios of tubers and of stolons to tops: Factorial analysis showed that the ratio of tuber/top varied only as the main effects, day length and night temperatures, were varied. For the stolon/top ratio significant effects were noted only for day length and day temperature.

Considering the tuber/top ratio (table 4) it may be noted that per gram of top, more tubers were produced under short days and the low

TABLE 4.—*Mean tuber/top and stolon/top ratios of significant main treatment effects*

Tuber/Top			
Day Length	Ratio	Night Temperature	Ratio
Long	.33	High	.23
Short	.80	Low	.90
Stolon/Top			
Day Length	Ratio	Night Temperature	Ratio
Long	.79	High	.44
Short	.37	Low	.73

night temperature level. This infers that day length had little or no effect on top growth, since both larger weight of tubers (table 2) and better yield per gram of tops occurred under short days. Night temperature, however, apparently did affect top growth. This is demonstrated by the efficacy of a low night temperature level in bringing about a better yield of tubers per gram of top weight, although as shown above a larger mean yield was produced under a high night temperature level.

An analysis of top weight data showed that day length did not significantly affect the growth of tops whereas night temperature did. The mean weight of tops for high and low night temperature levels was 36.8 grams and 12.7 grams, respectively. Obviously, therefore, a low night temperature, regardless of day length or day temperature, was more limiting to top growth than to tuber growth and a high night temperature had the reverse effect, thereby creating a greater ability of the top to produce tubers when the night temperature was 56° F. rather than 77° F.

Stolon weight per gram of top was greater under a long day which is logically explained, as for the tuber/top data, on the basis of top weight being unaffected by day length. The fact that a low day temperature brought about more stolons per gram of top infers that the tops were reduced in growth to a greater extent than were the stolons.

SECTIONAL NOTES

NEW YORK

The potato crop estimate on the 10th of September shows an increase of approximately one million bushels more than the August estimate. Following a generally hot, dry July, rains came in August in time to save the potato crop in many counties. Long Island will harvest a normal crop, though much smaller than the record crop of 1940. Because of the extreme drought, Northern New York will have one of the smallest crops in many years. Steuben County, the second most important potato county in the state, has had a very dry season. In the surrounding counties of western New York, conditions are spotted but, in general, not so bad as in Steuben County. Late blight has been reported in several localities but has not yet developed far enough to reduce the yield seriously. In Cortland County there are some 400-bushel yields being harvested. These, of course, have been grown under favorable conditions. (Sept. 13.)—E. V. HARDENBURG.

OHIO

The Cobbler crop in Ohio has yielded exceptionally well. Most of the Cobblers on the upland soil have been harvested but some growers have stored their crop, at least temporarily. At present we are harvesting in the muck area and an exceptionally good crop is being harvested.

The late crop has improved with the fall rains and cooler weather but many fields have irregular stands. The total production of the late crop is expected to be below normal.

The potato marketing association has been marketing potatoes largely in pecks and 50-lb. paper containers. The market has held steady with an average of about 23 cents per peck and 65 cents for 50-lbs.

Scab has been more serious than usual in this state and wireworm injury is exceptionally bad in Northwestern Ohio. The movement on ungraded stock has been slow. (Sept. 13.)—EARL B. TUSSING.

PENNSYLVANIA

We are completing the second inspection for certification and expect to have approximately 800 to 900 acres certified by the time the

final inspection is finished. Last year we certified 813 acres, and a total crop of approximately 220,000 bushels of seed. We anticipate a crop about equal to that of last year's production.

Weather conditions have been very spotty, with the result that in some areas the crop will be heavy, whereas, in others the yields will be small. Some areas have had both wet and dry periods. Tuber sets are generally light in these areas, and in most cases the tubers will not be too large.

In the Potter County area there has been an overabundance of moisture throughout most of the growing season. Late blight has damaged some foliage, and tuber rot has appeared. The tubers in this area will probably be large and in many cases over-sized. (Sept. 12.)—K. W. Lauer.

VERMONT

The early maturing of the potatoes appears to be rather general in Vermont. This may be attributed, in part, to earlier plantings than usual because of favorable weather, and partially, to extreme heat through a portion of the season.

A poor set has been reported by some larger growers, but in general a normal crop is expected. Late blight appeared in August and killed tops in some fields where spraying was insufficiently carried out, but to date (September 10th) comparatively little tuber rot has been reported. No positive cases of bacterial ring rot have, as yet, been found this season.

In our seed certification about 350 acres passed final inspection. The season was marked by no unusual outbreaks of virus diseases, and the use of more carefully selected foundation stock was reflected in low disease counts.

A research project on leaf roll control under Vermont conditions has been put in operation through cooperation of the Vermont Industrial Agricultural Products Commission, the State Experiment Station and the Vermont Department of Agriculture. (Sept. 12.)—H. L. Bailey.

Erratum:

The volume number of the August 1941 issue should read "18" and not "19" as printed on the cover page.

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SEED-SETTING IN POTATOES AS AFFECTED BY SPRAYING WITH A-NAPHTHALENEACETAMIDE AND BY LIGHT

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INTRODUCTION

A number of workers, including LaRue (6), Gardner and Marth (1, 2) and Gardner, Marth and Batjer (3, 4) have recently shown that certain so-called plant growth substances have an effect on the development of the abscission layer, thus preventing or retarding the dropping of flowers and fruits. With the apple, Gardner, Marth and Batjer found that naphthaleneacetic acid and a-naphthaleneacetamide were particularly effective in preventing fruit drop. The present study was undertaken to determine the effect of a-naphthaleneacetamide on the reduction of bud and flower drop in the potato, as the abscission of the buds and flowers is one of the most serious problems in potato breeding. The work was carried on at both Beltsville, Maryland, and Greeley, Colorado, to obtain information on flower and seed production under the environmental conditions prevailing at these two stations. The effect of somewhat higher concentrations of a-naphthaleneacetamide was tested at Presque Isle, Maine.

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MATERIALS AND METHODS

The varieties selected for the study were Irish Cobbler, Sebago, and S 245-25. The Irish Cobbler blooms profusely under field conditions in Maine and very sparsely in the greenhouse. It is highly pollen-sterile and rarely sets seed when self-pollinated. Sebago produces very little viable pollen and repeated attempts to self-pollinate it under field conditions at Presque Isle, Maine, have been unsuccessful. In the greenhouse at Beltsville, Maryland, and at Greeley, Colorado, a small amount of seed has been obtained by self-pollination. S 245-25 is a very fertile seedling variety which produces an abundance of fertile pollen under both field and greenhouse conditions.

Seed pieces of these varieties cut to approximately the same size were planted at Beltsville in soil in flats on the 15th of January, 1940. Twice as many seed pieces as were needed for the experiment were planted to permit selection. The flats were placed on the bench in the greenhouse and as soon as the plants emerged from the soil they were subjected to a photoperiod of approximately 17 hours by lengthening the period of natural daylight with Mazda light. Sixty-watt bulbs with 12-inch reflectors were used, each bulb serving twelve square feet of bench space. The intensity of this light at bench level ranged from approximately 20- to 30-foot candles. At first the lights were about 3½ feet above bench level, but as the plants grew the lights were raised. A temperature of 65° to 70° F. was maintained during the day and 45° to 50° F. at night.

Young plants were set in the greenhouse bench on the 5th of February and spaced 8 inches in rows one foot apart. Five blocks were planted, each block consisting of 12 plants of each of the three varieties. All plants were kept pruned to single stems. All flowers of S 245-25 were self-pollinated. The first inflorescence of each Sebago plant was self-pollinated; all subsequent flower clusters were crossed with S 245-25. All flowers were hand-pollinated several times. The first pollination was made at the late bud stage a day or two before the flower opened, as previous observations showed that in certain varieties, including Sebago, the buds are less likely to drop off if pollinated early. No flowers were produced on Irish Cobbler.

When buds began to appear on several plants, the terminal portion of each plant was sprayed with a-naphthaleneacetamide emulsion. Spraying was begun on the 12th of February and applications were applied at weekly intervals until the end of the flowering period. The emulsion was made up according to the formula of Hildreth and Mitchell

(5), a-naphthaleneacetamide being substituted for indolebutyric acid. Three concentrations, namely 0.0005, 0.001 and 0.002 per cent, were used in this experiment. Control plants were sprayed with an emulsion containing no a-naphthaleneacetamide. The spray treatments were randomized within each variety and block.

A similar planting was made at Greeley, Colorado, using seed pieces from the same source. The plants were grown under the same conditions insofar as they could be controlled, except that the planting was made one month earlier than at Beltsville, Maryland.

An experiment to test the effect of higher concentrations of a-naphthaleneacetamide was carried out in the greenhouse at Presque Isle, Maine, during the summer of 1940. Earlaine, a fertile variety, and also the Sebago variety were used. Earlaine was self-pollinated; Sebago was crossed with Earlaine. The plants were grown in the same manner as at Beltsville and Greeley, except that the strengths of the solutions were 0.004, 0.008, and 0.016 per cent, and only natural day-length was used.

Experimental Results

Table 1 shows that the a-naphthaleneacetamide spray at the concentrations used in this experiment had no effect on the number of inflorescences produced per plant at either Beltsville or Greeley. Under Beltsville conditions all Irish Cobbler buds abscissed at an early stage regardless of the spray treatment they received, and consequently have

Table 1.—*Effect of a-naphthaleneacetamide on the number of inflorescences per plant at Beltsville, Md., and Greeley, Colo.*

Spray Treatments	Beltsville, Md.			Greeley, Colo.			
	S 245-25	Sebago	(a) Mean	S 245-25	Sebago	Irish Cobbler	(a) Mean
Control	3.80	4.80	4.30	2.80	5.07	0.67	2.85
0.0005%	3.93	3.67	3.80	3.33	4.73	0.67	2.91
0.001%	3.67	3.80	3.74	3.20	4.40	0.40	2.67
0.002%	3.47	3.67	3.57	3.40	6.47	0.60	3.49
Mean	3.72(b)	3.98(b)		3.18(c)	5.17(c)	0.58(c)	

Difference required for significance at the 5 per cent level: (a) and (b) not significant; (c) 0.338 inflorescence.

been omitted from the table. At Greeley some of the Irish Cobbler plants produced mature flowers, although the number of inflorescences per plant was much less than for S 245-25 and Sebago. At both stations Sebago produced more inflorescences per plant than did S 245-25. At Beltsville the difference was not significant, but at Greeley the F value exceeded the 1 per cent point. The difference in number of inflorescences produced by S 245-25 at Beltsville as compared with Greeley was not significant. Sebago produced 5.17 ± 0.239 inflorescences per plant at Greeley and 3.98 ± 0.150 at Beltsville, the difference exceeding the 1 per cent level of significance.

The number of flowers per plant is shown in table 2. At Greeley the spray treatments produced no significant differences but at Beltsville the F value was significant to the 5 per cent level. The control plants at Beltsville actually produced more blossoms than those that were treated. Spraying, therefore, was not beneficial to flower production at either station.

TABLE 2.—*Effect of a-naphthaleneacetamide on the number of flowers per plant at Beltsville, Md., and Greeley, Colo.*

Spray Treatments	Beltsville, Md.			Greeley, Colo.			
	S 245-25	Sebago	(a) Mean	S 245-25	Sebago	Irish Cobbler	(b) Mean
Control	44.5	40.5	42.5	17.3	32.3	2.3	17.3
0.0005%	42.5	22.3	32.4	24.9	32.9	2.9	20.2
0.001%	41.1	28.6	34.8	17.7	30.3	1.9	16.6
0.002%	30.1	24.7	27.4	23.6	44.9	2.7	23.7
Mean	39.6(c)	29.0(c)		20.9(d)	35.1(d)	2.4(d)	

Difference required for significance at the 5 per cent level: (a) 4.908 flowers; (b) not significant; (c) 2.635 flowers; (d) 2.349 flowers.

At Beltsville S 245-25 produced significantly more blossoms per plant than Sebago, but at Greeley the condition was reversed. S 245-25 produced 39.6 ± 1.86 flowers per plant at Beltsville and only 20.9 ± 1.66 at Greeley, but a comparison of these means may be misleading as the counts were made on a slightly different basis at the two stations. At Beltsville the flowers were pollinated and counted before the petals had opened, whereas at Greeley they were counted afterwards. Consequently, the Greeley counts, owing to bud drop, may be considerably lower than they would have been if the flowers had been counted

at the earlier stage. At Beltsville, Sebago produced 29.0 ± 1.86, at Greeley, 35.1 ± 1.66 flowers per plant. This increase at Greeley is significant beyond the 1 per cent point. The Irish Cobbler plants did not bloom at Beltsville, but a few flowers were obtained at Greeley.

Data for seed ball production are given in table 3. The spray

TABLE 3.—*Effect of a-naphthaleneacetamide on the number of seed balls per plant at Beltsville, Md., and Greeley, Colo.*

Spray Treatments	Beltsville, Md.			Greeley, Colo.			
	S 245-25	Sebago	(a) Mean	S 245-25	Sebago	Irish Cobbler	(a) Mean
Control	12.3	4.8	8.6	8.4	5.6	0.9	5.0
0.0005%	14.7	1.4	8.1	13.0	5.4	1.3	6.6
0.001%	10.7	2.9	6.8	7.5	4.9	0.1	4.1
0.002%	7.7	1.9	4.8	10.8	7.4	1.1	6.4
Mean	11.4(b)	2.8(b)		9.9(c)	5.8(c)	0.8(c)	

Difference required for significance at the 5 per cent level: (a) not significant; (b) 1.106 seed balls; (c) 0.846 seed ball.

treatments had no significant effect on the number of seed balls produced at either Beltsville or Greeley. The number of seed balls per plant appeared to diminish at Beltsville as the concentration of the solution increased, but the differences were too small to be interpreted as significant and the results at Greeley showed no such trend. In any event, spraying with a-naphthaleneacetamide did not increase the number of seed balls and was of no practical benefit.

At both Beltsville and Greeley the Sebago plants produced significantly fewer seed balls than S 245-25. This reduction resulted partly from the self-pollination of the first inflorescence of the Sebago plants, since Sebago is highly pollen sterile and is therefore difficult to self. Presumably a few more seed balls would have been obtained from the Sebago plants if this first flower cluster, like the later ones, had been crossed with S 245-25. However, when the seed balls formed from the first flower cluster at Beltsville were omitted, the difference between the two varieties was still highly significant.

The difference in number of seed balls produced by S 245-25 at the two stations was not significant, but Sebago produced more than twice as many seed balls at Greeley. This increase exceeded the 1 per cent

level of significance. Irish Cobbler produced no seed balls at Beltsville, but did produce a few at Greeley.

The concentrations of a-naphthaleneacetamide used at both Beltsville and Greeley were 0.0005, 0.001 and 0.002 per cents. As no positive results were obtained from these, stronger solutions of 0.004, 0.008 and 0.016 per cents were tested at Presque Isle during the summer of 1940. The sprayed plants produced significantly fewer flowers than the controls, as shown in table 4. This decrease was observed for both Sebago

TABLE 4.—*Effect of a-naphthaleneacetamide on the number of flowers per plant at Presque Isle, Me.*

Spray Treatments	Earlaine	Sebago	(a) Mean
Control	5.2	38.5	21.8
0.004%	3.1	23.7	13.4
0.008%	3.0	22.1	12.6
0.016%	1.9	18.0	10.0
Mean (b)	3.3	25.6	

Difference required for significance at the 5 per cent level: (a) 3.88 flowers; (b) 2.96 flowers.

and Earlaine. These stronger concentrations unquestionably had an unfavorable effect on flower development.

DISCUSSION

In these experiments a-naphthaleneacetamide was not effective in reducing bud and flower drop in the potato. With the higher concentrations used at Presque Isle the number of flowers was actually reduced. Gardner, Marth and Batjer (4) found that with the apple the application of growth substances was not effective on blossoms and young fruits, although it did delay the abscission of mature fruits. They point out that the anatomical changes in the abscission layer accompanying the drop of mature fruits differ from those controlling the early drop of flowers and young fruits, and may account for the difference in effectiveness of growth substances at the two stages of development. This view offers an explanation for the failure to prevent drop in the potato, as reported in this paper, since the loss results from the abscission of buds and flowers, and the seed ball or fruit rarely drops after it starts to develop.

The differences in varietal response at Beltsville and Greeley probably result chiefly from the difference in natural light intensity, because otherwise the plants were given similar treatment. During the winter months there is relatively little cloudy weather at Greeley, so that the total amount of solar energy is greater there than at Beltsville. At both places S 245-25 flowered and set fruit more abundantly than the other two varieties. Relatively few buds and flowers were shed by this variety even under Beltsville conditions, so that growing it in the more favorable Greeley environment did not increase flower and seed ball production. Both Sebago and Irish Cobbler produced more seed balls at Greeley than at Beltsville. Apparently, each of these varieties was affected adversely by the Beltsville environmental conditions to a greater extent than was S 245-25.

Summary

Spraying potato plants with dilute concentrations of a-naphthaleneacetamide was not effective in increasing flower or seed ball production in the greenhouse at Beltsville Maryland, or Greeley, Colorado. Higher concentrations reduced flower production at Presque Isle, Maine.

Sebago and Irish Cobbler produced more seed balls at Greeley than at Beltsville. Less cloudy weather at Greeley during the winter months is probably the chief factor responsible for this result.

S 245-25, when self-pollinated, produced as many seed balls at Beltsville as at Greeley. It appears that this variety flowers and sets seed more readily under fairly unfavorable light conditions than either Sebago or Irish Cobbler.

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BREEDING A POTATO RESISTANT TO THE POTATO LEAFHOPPER

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INTRODUCTION

The potato is subject to injury by a number of insects, one of the most destructive of which is the potato leafhopper, *Empoasca fabae* Harris. DeLong (6) records this insect as an important pest in the Eastern, Middle Western, and North Central states.

The injury produced by the feeding of the adults or the nymphs of the potato leafhopper is known as "hopperburn." According to DeLong (6) this condition is characterized by the distortion of the leaf veins and a consequent yellowing of the tissue around the margin and at the tip of the leaf. This is soon followed or accompanied by a rolling upward and inward of the margins as the leaf changes from yellow to brown and becomes dry and brittle. Although hopperburn usually begins with a spot at the tip of the apical leaflet the discoloration and curling rapidly spread until the whole leaf is dry and dead. The portion which remains green longest is a central area along the midrib, especially at the base near the petiole. When the insect infestation is heavy the entire plant is usually killed in a short time.

Stuart (13) said, "While it is very difficult to estimate the amount of injury to the potato crop as a result of leafhopper attacks, it is safe to say that when these insects are abundant they naturally lessen the yield." In some fields of both early and late potatoes observed by the writer in 1919, the indications were that the yield had been reduced fully 50 per cent.

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Hyslop (9) reported that in Wisconsin, Ohio, Illinois, Indiana and Michigan the leafhopper is a serious pest. The annual loss in the potato crop in these five states caused by this insect varies from 10 to 18 per cent, with an average of 14 per cent, or approximately 12,000,000 bushels, which at the low regional prices prevailing would have a value of $7,000,000. To this would be added the cost of spraying. In 1938 only one-fifth of the crop in this section was sprayed, but the estimated spray bill was $250,000. One-half of this amount was considered chargeable to other insects and to plant diseases, leaving $125,000 to be charged to leafhopper control. Any estimates of losses are, of course, subject to error, but the fact remains that large reductions in yield can be attributed to the potato leafhopper.

That certain growth factors are associated with populations of nymphs and reactions to leafhopper injury has been shown by a number of investigators. Sleesman and Bushnell (11) counted the nymphal populations on 15 potato varieties under natural conditions of infestation. An analysis of the data showed a significant difference among leafhopper populations. The early-maturing were more heavily infested than the late-maturing varieties. The correlation between population and maturity was significant.

Maughan (10) reported that in a study of 11 commercial varieties hopperburn was associated with the stage of growth of the plant. The foliage of the early-maturing types was severely affected during the latter part of July, whereas only approximately 50 per cent of the leaves of the late-maturing varieties were affected on the 1st of September. Also, the late-maturing types were definitely infested with fewer insects.

Ball (3) reported that tipburn has been used by pathologists for many years as a term to designate any burned condition of the leaves for which no causal agent could be found. Various theories have been advanced regarding its cause, the most commonly accepted one being that of too rapid transpiration under certain abnormal conditions of temperature and soil moisture. "It seems probable," he said, "that a considerable amount of the injury referred to as tipburn in the past has been caused by leafhopper. It was thought that there was a considerable varietal difference in susceptibility to attack and that Triumph, Irish Cobbler, Early Ohio, Green Mountain, and Rural were affected in approximately the order named, the Rural the least. Further studies indicated, however, that most of this variation was caused by a difference in the time that these plants required for developing sufficient foliage to furnish a place for egg deposition for the spring brood of

adults. "There may be a varietal difference," the author said, "but it will be necessary to investigate this with reference to the relative amount of foliage produced in a given time, rather than to date of planting."

The limited amount of work that has been done in testing varieties and species of potatoes shows that there are wide differences among them, and that there are possibilities of breeding varieties resistant or even immune to leafhopper attacks.

Allen and Rieman (1) found that, in general, the early-maturing are more susceptible to leaf hopper injury than the late-maturing varieties. Among the susceptible varieties Triumph, Warba, Earlaine, and White Blossom Cobbler showed a high level of susceptibility. Among the resistant ones were Pioneer, Rural, Houma, Katahdin and Russet Rural. The hopperburn tolerance exhibited by Houma and Katahdin may account in part for the heat and drought resistance attributed by various investigators to these two varieties. A number of seedling cultures that show a greater degree of resistance and susceptibility than any of the new or old varieties were isolated.

Allen *et al.* (2) reported the results of a study to determine the influence of planting date on the percentage of hopperburn development and upon the leafhopper population. They found that hopperburn development was greater in the early varieties than in the late varieties, regardless of the planting date. Percentage of hopperburn development was reduced by deferring the planting date with both early and late varieties. Nymphal leafhopper population was closely correlated with the percentage of hopperburn development with respect to time of planting. The results indicated that the relative earliness or lateness of a variety is not the prime factor in determining its resistance or susceptibility to hopperburn.

Sleesman (12) tested a number of wild species of *Solanum* for resistance to hopperburn. *Solanum polyadenium* was found to be highly resistant, if not immune. *S. chacoense, S. commersonii* and *S. caldasii* were highly resistant.

MATERIALS AND METHODS

When the present program of breeding for late-blight resistance was begun in 1932 by the Bureau of Plant Industry, leafhopper injury was not given consideration. It soon became apparent, however, that a variety resistant to late blight must be resistant also to insect attacks, especially to hopperburn, if spraying is to be reduced to a minimum. Accordingly, in 1934 a program of breeding for hopperburn resistance

was begun at Oakland, Md., in cooperation with the Maryland Agricultural Experiment Station. The parent varieties and progenies tested at other stations for resistance to late blight were given major emphasis.

The hopperburn test plots at Oakland were not sprayed with bordeaux throughout the growing season, so heavy infestations of leafhoppers usually occurred. At first it was considered desirable to study reaction to leafhoppers and late blight on the same plots, but in 3 years—1934, 1935 and 1936—in which the tests were made at Oakland, a late blight epidemic occurred only once. In 1935 a heavy infestation of leafhoppers was followed by a severe epidemic of late blight. The leafhopper data seemed reliable for comparative purposes, but when the late blight data were taken 2 weeks later, it was difficult to separate hopperburn from late blight injury and in many cases the total necrosis of the leaves was attributed to the latter.

It was evident that if the true relationship were to be obtained, the two tests would have to be run independently. The tests for leafhopper injury reported in this paper were made, therefore, in the field at Oakland or at Beltsville, Md., or at McGuffey, Ohio, and the late-blight data used in calculating the correlations between leafhopper injury and reactions to this disease were secured in the greenhouse at Arlington Farm, Va., or Beltsville, Md.

In 1934 and 1935 hopperburn data at Oakland were recorded in 6 classes as follows:

0 = No injury.
1 = Trace to 20 per cent leaf area injured.
2 = 21 per cent to 40 per cent leaf area injured.
3 = 41 per cent to 60 per cent leaf area injured.
4 = 61 per cent to 80 per cent leaf area injured.
5 = 81 per cent to 100 per cent leaf area injured.

In 1936 at Oakland and from 1937 to the present at Beltsville 4 classes have been used:

1 = 0 per cent to 25 per cent leaf area injured.
2 = 26 per cent to 50 per cent leaf area injured.
3 = 51 per cent to 75 per cent leaf area injured.
4 = 76 per cent to 100 per cent leaf area injured.

Seedlings from selfed lines and crosses have been planted in 5- to 10-hill plots in the field with Green Mountain and President (4)

throughout the field as checks. The Green Mountain is moderately susceptible to hopperburn; the President is usually but not always more resistant. In 1938, 1939, and 1940 at McGuffey, Ohio, the seedlings from selfed lines and crosses were planted in 5- to 10-hill single-row plots in the field with Irish Cobbler as a check variety. All of the sorts were planted insofar as possible on the same date and were not sprayed with either insecticides or fungicides during the entire growing season. Where sufficient seed stock was available each seedling was planted in threefold randomized replications.

The method used in estimating leafhopper populations was to count the nymphs on 5 to 10 leaves selected at random from each plot. Nymphs seldom leave the plant and may be readily counted upon an individual leaf. The adults, however, are very active and move freely from one plant to another and from row to row; therefore, the nymphal count was considered the better index to relative populations.

The varieties named below were used as parents for the various selfed and crossed progenies tested for leafhopper resistance. Fourteen of the progenies tested in the field for hopperburn were tested also for late-blight resistance in the greenhouse either at Arlington Farm, Va., or at Beltsville, Md.

Katahdin shows only a small degree of resistance to hopperburn, but it has many other characters that make it a desirable parent. It carries a gene or genes for resistance to late blight. It produces a well-shaped tuber, is immune in the field to mild mosaic, is vigorous and high-yielding, and produces an abundance of viable pollen under a wide range of environmental conditions.

The President, a variety described by Bonde (4), under the name Foster's Rustproof, is on the average more resistant to hopperburn than the Katahdin. It is also resistant to late blight, and for these reasons it was used not only as a parent but also as a check in the tests.

Ackersegen is a yellow-flesh late variety obtained from Germany. It is resistant not only to late blight but to common scab and potato wart. It is somewhat resistant to leafhopper injury, but its yields are rather low and the tubers are not well shaped. Despite its resistance, its yellow flesh and extreme lateness make it undesirable as a parent in a breeding program that has for its objectives white-flesh early varieties.

Earlaine is a highly self-fertile variety as early as Irish Cobbler and, under favorable conditions, yields about the same as the latter variety but produces a much smoother type of tuber. It is immune to mild mosaic under field conditions.

TABLE 1.—*Hopperburn data for progenies and check varieties grown at Oakland, Md., 1934, 1935 and 1936.*

Pedigree No.	Parentages and Check Varieties	Year Tested	No. of Seedlings or Checks	Percentages of Seedlings Placed in the Several Classes of Hopperburn[1] 0	1	2	3	4	5	Mean
				Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Class
I 1241	Katahdin selfed	1934	78	2.6	19.2	16.7	26.9	34.6	—	2.7 ± .14
I 1241	do	1935	50	2.0	24.0	42.0	24.0	4.0	4.0	2.2 ± .15
X 336	President x Katahdin	1934	442	4.3	28.7	24.9	19.9	22.2	—	2.3 ± .06
X 336	do	1935	160	3.8	28.1	28.7	25.0	14.4	—	2.2 ± .09
X 665	Ackersegen x Earlaine	1935	67	4.5	41.8	17.9	22.4	10.4	3.0	2.0 ± .15
X 665	do	1936	70	—	7.1	50.0	20.0	22.0	—	2.6 ± .11
X 678	Ackersegen x Katahdin	1935	405	6.4	43.0	30.4	12.8	2.2	5.2	1.6 ± .05
X 678	do	1936	410	—	15.9	52.2	20.2	11.7	—	2.3 ± .04
	Katahdin	1935	19	—	52.6	42.1	5.3	—	—	1.5 ± .14
	do	1936	23	—	—	26.1	69.6	4.3	—	2.8 ± .11
	Ackersegen	1935	22	—	13.6	40.9	45.5	—	—	2.3 ± .15
	do	1936	25	—	8.0	88.0	4.0	—	—	2.0 ± .07
	Earlaine	1935	7	—	—	—	—	—	100	5.0
	do	1936	8	—	—	—	—	100	—	4.0
	President	1934	60	3.3	51.7	43.3	1.7	—	—	1.4 ± .08
	do	1935	50	—	12.0	52.0	36.0	—	—	2.2 ± .09
	do	1936	91	—	2.2	97.8	—	—	—	2.0 ± .02
	Green Mountain	1934	62	—	—	19.3	40.3	40.3	—	3.2 ± .09
	do	1935	44	—	15.9	38.6	27.3	13.6	4.5	2.5 ± .16
	do	1936	94	—	9.6	39.3	35.1	16.0	—	2.6 ± .09

[1] In 1934 and 1935 leafhopper injury data were recorded in 6 classes as follows:

0 = No injury.
1 = Trace to 20 per cent leaf area injured.
2 = 21 to 40 per cent leaf area injured.
3 = 41 to 60 per cent leaf area injured.
4 = 61 to 80 per cent leaf area injured.
5 = 81 to 100 per cent leaf area injured.

From 1936 to the present the data were recorded in 4 classes:

1 = 0 to 25 per cent leaf area injured.
2 = 26 to 50 per cent leaf area injured.
3 = 51 to 75 per cent leaf area injured.
4 = 76 to 100 per cent leaf area injured.

3897-90 is a blight-resistant early selection, the seed of which was received from K. O. Müller, Berlin-Dahlem, Germany.

Albion was received from The Institute for Plant Breeding, Wageningen, Holland. It was supposed to be somewhat resistant to leafroll but has not proved so in tests in this country.

Results

Two progenies, one Katahdin selfed, the other President x Katahdin, were tested for hopperburn resistance in comparison with Green Mountain and President at Oakland, Maryland, in 1934 and 1935. In 1934 the mean for the Katahdin progeny was 2.7 with corresponding means for Green Mountain and President of 3.2 and 1.4 respectively. If the progeny is considered as a whole it is significantly more resistant than Green Mountain, but more susceptible than President as shown in table 1. Twenty-one and eight-tenths per cent of the seedlings suffered less injury than the least-injured Green Mountain check, and 34.7 per cent were in a class with the most heavily injured Green Mountain. That the progeny showed a much wider range of reactions to hopperburn than the Green Mountain is evidence of genetic segregation.

Similar results were obtained for the cross President x Katahdin. It might be expected that this cross would show greater resistance than the progeny of Katahdin selfed, since President has usually shown greater resistance than Katahdin. The chi-square test calculated from the numbers of seedlings in each category instead of percentages shows, however, that the two samples could be drawn at random from the same population more than 5 per cent of the time. Ackersegen x Earlaine and Ackersegen x Katahdin were both significantly more resistant than the Green Mountain checks in 1935, the chi-square values exceeding the 5 per cent and 1 per cent levels, respectively. There was no significant difference between the reactions of the two progenies, Ackersegen x Earlaine, and President x Katahdin, in 1935, but the probabilities were better than 99:1 that the Ackersegen x Katahdin cross was more resistant than Ackersegen x Earlaine.

If the same comparisons are made for 1936, however, the record is not so good. Most of the seedlings found in classes 0 and 1 in 1935 were found in class 2 in 1936. The Green Mountain checks were more severely injured also. Fifty-seven and one-tenth per cent of the seedlings of Ackersegen x Earlaine were found in classes 1 and 2 in comparison with 15.9 per cent of the Green Mountain plots. This might indicate the same relationship between the progeny and the Green Mountain as was shown in 1935. The chi-square test, shows however,

TABLE 2.—*Reaction to hopperburn of selfed lines and crosses tested in comparison with check varieties fro[m] 1936 to 1939, inclusive.*

Pedigree No.	Parentages and Check Varieties	Year Tested	No. of Seedlings or Checks	Percentages of Seedlings Placed in the Several Classes of Hopperburn: 1	2	3	4	Mean
				Per Cent	Per Cent	Per Cent	Per Cent	Class
	336-50 selfed	1936	90	46.7	43.3	5.6	4.4	1.7 ± .08
	do	1937	84	19.0	35.7	29.8	15.5	2.4 ± .11
	336-96 selfed	1936	93	33.3	65.6	1.1	—	1.7 ± .05
	do	1937	80	2.5	32.5	42.5	22.5	2.9 ± .09
	336-153 selfed	1936	152	34.2	63.2	2.6	—	1.7 ± .04
	do	1937	156	12.8	48.1	33.3	5.8	2.3 ± .06
	336-140 selfed	1937	69	31.9	53.6	13.0	1.5	1.8 ± .08
	336- 18 selfed	1938	104	12.5	46.2	37.5	3.8	2.3 ± .07
X 123	336- 7 x 336-18	1938	67	9.0	74.6	14.9	1.5	2.1 ± .07
X 123	do	1939	54	—	46.3	51.9	1.8	2.6 ± .07
X 811	336-123 x 336-18	1938	118	12.7	61.0	24.6	1.7	2.2 ± .06
X 788	336-144 x 336-18	1939	54	5.5	68.5	9.3	16.7	2.4 ± .11
X 527	336-123 x S 46422	1938	130	14.6	37.7	26.9	20.8	2.5 ± .09
X 527	do	1939	49	10.2	44.9	40.8	4.1	2.4 ± .10
X 617	336-144 x S 46197	1938	145	15.8	55.2	21.4	7.6	2.2 ± .07
X 617	do	1939	102	—	30.4	60.8	8.8	2.8 ± .06
X 698	3897-90 x 336-18	1938	106	36.8	47.2	14.1	1.9	1.8 ± .07
X 698	do	1939	66	45.5	45.5	9.0	—	1.6 ± .08

that the seedlings and the Green Mountain plots could be drawn from the same population more than 5 per cent of the time. This is not much of a change, however, since P for this comparison in 1935 was slightly less than .05 and only slightly more than .05 in 1936. The Ackensegen x Katahdin cross was more severely injured in 1936 than in 1935, but the chi-square test indicates that it was again more resistant than either the Green Mountain checks or the Ackersegen x Earlaine progeny, the odds being better than 99:1 for the comparison with the Green Mountain and better than 19:1 when the two progenies were compared.

The 4 progenies in table 1, with the possible exception of Ackersegen x Earlaine, show segregation for resistance and susceptibility and a significantly higher degree of resistance than the Green Mountain variety.

A number of blight-resistant selections were made from the President x Katahdin cross 336. Some of these were selfed some sib-crossed, and some outcrossed as will be noted in table 2. Selfed lines derived from 336-50, 336-96, and 336-153 were tested for hopperburn at Oakland in 1936 and at Beltsville in 1937. The means were 1.7 for the 3 progenies at Oakland compared with 2.6 for the Green Mountain checks, a highly significant difference. In 1937 at Beltsville, however, the differences were not so great. The means for the progenies were 2.4, 2.9, and 2.3, respectively, with 3.0 for the Green Mountain. It might appear that there is not a significant difference between the 336-96 progeny with a 2.9 mean and Green Mountain with a mean of 3.0. The chi-square test calculated on the basis of the numbers found in the several classes shows, however, that a significant difference does exist.

The other progenies of this same group, 336-140 and 336-18 selfed, gave similar results. The progeny from 336-140 averaged 2.3 in 1938, but the Green Mountain was more severely injured with an average of 3.7.

It thus appears that all 5 selfed lines from the President x Katahdin cross 336 showed a segregation for resistance and susceptibility to hopperburn and each family was significantly more resistant than Green Mountain. A similar statement could be made concerning the sib-crosses 336-7 x 336-18, 336-123 x 336-18, and 336-144 x 336-18. When the crosses are compared among themselves on a chi-square basis, however, there is no significant difference between the first two for 1938, but 336-144 x 336-18 showed a greater resistance than 336-7 x 336-18 in 1939.

TABLE 2—*Continued*

Pedigree No.	Parentages and Check Varieties	Year Tested	No. of Seedlings or Checks	Percentages of Seedlings Placed in the Several Classes of Hopperburn				
				1	2	3	4	Mean
				Per Cent	Per Cent	Per Cent	Per Cent	Class
X 156	Albion x Katahdin	1939	127	0.8	20.5	55.9	22.8	3.0 ± .06
X 165	Albion x Earlaine	1939	169	—	2.4	29.6	68.0	3.7 ± .04
	336-7 check	1938	7	—	100.0	—	—	2.0 ±
	do	1939	7	—	—	71.4	28.6	3.3 ± .17
	336-18 check	1938	29	—	79.3	20.7	—	2.2 ± .08
	do	1939	11	—	18.2	81.8	—	2.8 ± .12
	336-123	1938	11	—	27.3	63.6	9.1	2.8 ± .17
	do	1939	3	—	—	66.7	33.3	3.3 ±
	Katahdin	1936	23	—	26.1	69.6	4.3	2.8 ± .11
	do	1937	2	—	100.0	—	—	2.0 ±
	President	1936	91	2.2	97.8	—	—	2.0 ± .02
	do	1937	40	—	12.5	87.5	—	2.9 ± .05
	do	1938	57	—	10.5	70.2	19.3	3.1 ± .07
	do	1939	28	3.6	57.1	39.3	—	2.4 ± .10
	Green Mountain check	1936	94	9.6	39.3	35.1	16.0	2.6 ± .09
	do	1937	44	—	—	97.7	2.3	3.0 ± .02
	do	1938	70	—	2.9	27.1	70.0	3.7 ± .06
	do	1939	112	—	8.9	48.2	42.9	3.3 ± .06

TABLE 3.—*Correlations between resistance to leafhopper injury in the field and late blight resistance in the greenhouse.*

Pedigree No.	Parentage	No. of Seedlings	r	P	Significance Based on 5-Per Cent Level
I 1241	Katahdin selfed	80	[1] .1472	Greater than .05	Not significant
X 336	President x Katahdin	444	[1] .2690	Less than .01	Significant
—	336-50 selfed	73	[2] .3724	do	do
—	336-96 selfed	79	[2] .0423	Greater than .10	Not significant
—	336-140 selfed	65	[2] —.0738	do	do
—	336-153 selfed	155	[2] .2032	Approaches .01	Significant
—	336- 18 selfed	78	[3] —.2301	Slightly less than .05	do
X 811	336-123 x 336-18	102	[3] .0474	Greater than .10	Not significant
X 617	336-144 x 46197	137	[3] —.0944	do	do
X 123	336- 7 x 336-18	65	[3] .0695	do	do
X 554	336-302 x 46422	19	[3] .0450	do	do
X 653	336-302 x 46197	31	[3] —.0060	do	do
X 527	336-123 x 46422	124	[3] .1820	Greater than .05	do
X 698	3807- 90 x 336-18	58	[3] .2256	do	do

[1]Hopperburn in the field at Oakland, Md., 1934, correlated with late blight resistance in the greenhouse at Arlington, Va., 1934.
[2]Hopperburn in the field at Beltsville, Md., 1937, correlated with late blight resistance in the greenhouse at Beltsville, Md., 1937.
[3]Hopperburn in the field at Beltsville, Md., 1938, correlated with late blight resistance in the greenhouse at Beltsville, Md., 1938.

A high degree of resistance was shown by the cross 3897-90 x 336-18 in 1938 with a mean of 1.8 and again in 1939 with a mean of 1.6. Two crosses 336-123 x S 46422 and 336-144 x S 46197 showed a higher degree of resistance than Green Mountain for both 1938 and 1939.

Albion x Katahdin was more resistant to hopperburn than the Green Mountain in 1939, but Albion x Earlaine was more susceptible, as judged by the means and standard errors. According to the chi-square test the odds are better than 99:1 that Albion x Katahdin is more resistant than Albion x Earlaine, which would indicate that Katahdin has genes for resistance which are not found in Earlaine.

Correlations between Resistance to Hopperburn and to Blight

As the chief interest in this problem from the breeding standpoint has been the development of new varieties resistant to both late blight and hopperburn, a number of progenies were tested for these characters and the correlations determined, as shown in table 3.

The leafhopper tests were made in the field, and the late blight tests in the greenhouse. Of the 14 progenies in both tests 3 of them, President x Katahdin, 336-150 selfed, and 336-153, showed comparatively small but significant positive correlations between the two characters; and one, 336-18 selfed, showed a small negative correlation with probabilities for significance barely exceeding 19:1. All other progenies gave correlations that were not significant.

It would have simplified the breeding problem greatly if a high correlation existed between these two characters. A seedling variety selected for late blight resistance also has comparatively little chance of being resistant to hopperburn, in view of the small correlations shown for the 14 progenies in table 3. Even though the correlation coefficient .2690 for the President x Katahdin cross is significant, it is relatively unimportant since only a small percentage of the 444 seedlings would have a chance of being resistant to both late blight and hopperburn. It will have to be admitted that the chances of finding a promising commercial variety combining all the other characters of economic importance in such a small group are very remote.

Nymph Populations

The results so far reported in this paper are based on leafhopper injury, and wide differences have been found between varieties and

TABLE 4.—*Leafhopper nymph counts and hopperburn for progenies of selfed lines and crosses tested at McGuffey, Ohio, in 1938 and 1939. Data for Irish Cobbler are given for comparison.*

Pedigree No.	Parentages and Check Varieties	Year Tested	Test	No. of Seedlings or Checks	Percentages of Seedlings in the Several Classes for Nymph Counts or Hopperburn						
					1	2	3	4	5	6	Mean
					Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Per Cent	Class
X 123	336-7 x 336-18	1938	Nymphs	64	18	44	2	—	—	—	1.8 ± .06
X 123	do	1939	do	61	8	20	25	8	—	—	2.5 ± .11
X 123	do	1939	Hopperburn	61	3	12	35	11	—	—	2.9 ± .12
X 811	336-123 x 336-18	1938	Nymphs	160	99	61	—	—	—	—	1.4 ± .04
X 811	do	1939	do	164	11	93	52	8	—	—	2.3 ± .05
X 811	do	1939	Hopperburn	164	—	8	49	91	16	—	3.7 ± .06
X 810	Ackersegen x 336-18	1938	Nymphs	34	9	25	—	—	—	—	1.7 ± .08
X 810	do	1939	do	33	4	14	12	3	—	—	2.4 ± .14
X 810	do	1939	Hopperburn	33	—	2	7	21	3	—	3.8 ± .12
X 617	336-144 x S 46197	1938	Nymphs	36	7	27	2	—	—	—	1.9 ± .08
X 617	do	1939	do	32	1	11	15	3	2	—	2.8 ± .16
X 617	do	1939	Hopperburn	32	—	3	2	12	15	—	4.2 ± .16
—	336-18 selfed	1938	Nymphs	89	33	48	7	—	1	—	1.7 ± .07
—	do	1939	do	88	6	40	35	7	—	—	2.5 ± .24
—	do	1939	Hopperburn	88	4	9	22	50	3	—	3.4 ± .30
X 627	Hindenburg x Katahdin	1938	Nymphs	49	37	12	—	—	—	—	1.2 ± .06
X 627	do	1939	do	54	—	12	38	4	—	—	2.9 ± .07
X 627	do	1939	Hopperburn	54	—	3	10	24	17	—	4.0 ± .12
—	Katahdin selfed	1938	Nymphs	130	97	20	6	4	2	1	1.4 ± .08
—	do	1939	do	152	28	78	42	3	1	—	2.2 ± .19
—	do	1939	Hopperburn	152	3	18	17	53	61	—	4.0 ± .09
—	Irish Cobbler	1938	Nymphs	5	—	—	—	—	—	—	3.0 ±
—	do	1939	do	14	—	6	6	2	—	—	2.7 ± .03
—	do	1939	Hopperburn	14	—	—	1	—	13	—	4.9 ± .17

[1]Leafhopper populations were determined by counting the nymphs on 5 leaves selected at random from each plot. The classes in which nymph count means were grouped for convenience of tabulation were as follows:

1 = 0 — 5	4 = 16 — 20
2 = 6 — 10	5 = 21 — 25
3 = 11 — 15	6 = 26 — and over

seedlings in their reactions to such injury. The question naturally arises, whether there are corresponding differences in leafhopper populations on the various sorts and how closely the two are correlated. Nymph counts are considered the most satisfactory index of leafhopper populations since, unlike the adults, they seldom leave the plant and may readily be counted on an individual leaf.

In 1937 a study of nymph populations and their relation to hopperburn was begun at McGuffey, Ohio. A preliminary test that year of more than 400 seedlings and varieties indicated a wide variation in infestations. That these were not all chance variations but were dependent to some degree on varietal differences is indicated by the results obtained the following year. Thirty-two seedlings that had shown nymph populations greater than 10 per leaf in 1937, and 62 that had shown less than 3 per leaf were planted in 3 replications. The populations the second year were, on the average, greater than in the preceding year, but the seedlings that carried a high population in 1937 were found with few exceptions in the high class the following year, with corresponding results for those with low counts. The average for the high population group was 12.6± .79, and for the low 6.5± .45.

Five crosses and 2 selfed lines were tested for nymph populations in 1938 and for nymph populations and hopperburn in 1939. The data for these tests are given in table 4. Many of the seedlings of the 7 progenies showed comparatively light nymph populations the first year. Of 562 seedlings reported in the table, about 300 showed mean counts of 5 or less nymphs per leaf. In comparison with this, the Irish Cobbler plots averaged more than 10 nymphs per leaf.

In 1939 the nymph populations were higher on the average than they were in 1938 as is shown by a comparison of the means of each of the progenies and of the check variety. Of a total of 594 seedlings tested in 1939, more than 300 had fewer nymphs per leaf than the Irish Cobbler.

Comparing the results for the 2 years on the basis of the number of seedlings with fewer nymphs per leaf than were found on the check variety, it might seem that even if the infestation as a whole were higher in 1939 than it was in 1938, there should still be significant correlations betewеen the counts for the 2 years.

These correlations calculated for each of 5 progenies were not significant as will be observed from table 5. This would indicate that nymph counts should be made over a period of years if definite conclusions are to be drawn. Correlations between nymph populations and hopperburn for 1939 were calculated for these same 5 progenies. In

TABLE 5.—*Correlations between nymph counts for the years* 1938 *and* 1939, *and between nymph counts and hopperburn for* 1939.

Pedigree No.	Parentages	Number of Seedlings	r[1]	r[2]
X 123	336-7 x 336-18	61	.1905	[3] .3186
X 810	Ackersegen x 336-18	33	.1202	.2864
X 617	336-144 x S 46197	32	—.0695	.1266
——	336-18 selfed	84	.1790	.1314
——	Katahdin selfed	114	.0338	.0656

[1]Nymph counts in 1938 correlated with nymph counts in 1939.
[2]Nymph counts correlated with hopperburn in 1939.
[3]Exceeds the 5 per cent level of significance.

only one of these did the correlations between the two exceed the 5 per cent level, and the magnitude of this was relatively small ($r = .3186$). It is evident, therefore, that in these progenies the differences in seedling reactions to hopperburn are not all caused by the differences in leafhopper populations. Many factors contribute to the observed variations, but differences among progenies, among check varieties, and between some progenies and the check varieties are so great that there is much evidence of genetic differences.

In 1940, 18 named varieties and 73 numbered seedlings,—the latter group selected for their apparent resistance in previous tests, were grown in three replications. Nymph counts and hopperburn estimations were made on all plots. The data for these tests are given in table 6, with the distribution of the 73 seedlings according to (a) nymph counts and (b) hopperburn class. The analysis of variance indicates that there was no significant difference between replicates either for nymph counts or hopperburn, but the F values for varieties for both exceed the 1-per cent level.

The difference between means of nymph counts required for significance at the 5 per cent level is 17.9. Comparisons made between the mean nymph counts on this basis show that Bliss Triumph was significantly more heavily infested than any other named variety or any but one of the seedlings.

Houma, Nonesuch, Katahdin, Rural New Yorker No. 2, Richter's Jubel, Paisley No. 2, Up-to-Date, and 30 of the numbered seedlings had significantly lighter infestations than the Irish Cobbler. Irish Cobbler had 45 nymphs per leaf and showed a 3 degree of injury, but Red Warba and Earlaine with about two-thirds as many nymphs,

TABLE 6.—*Nymph counts and hopperburn in 1940 on varieties and seedlings, the latter selected for their resistance or tolerance in previous tests.*[1]

Varieties and Seedlings Tested	Number of Nymphs per 5 Leaves. Mean of 3 Replications[2]	Class of Hopperburn. Mean of 3 Replications[2]
Irish Cobbler	45	3.0
Warba	44	3.0
Red Warba	31	3.0
Bliss Triumph	75	3.0
Earlaine	31	3.0
Pontiac	51	3.0
Houma	23	2.3
Nonesuch	13	3.0
Chippewa	35	2.3
Sebago	35	1.7
Katahdin	22	2.0
Sequoia	40	1.3
Rural New Yorker No. 2	20	1.3
Hindenburg	28	2.0
Richter's Jubel	16	2.0
Paisley's No. 2	22	2.0
Blue Salad	48	1.7
Up-to-Date	27	2.3
(a)[3] 6 Seedlings	15–20	—
16 "	21–25	—
25 "	26–30	—
9 "	31–35	—
8 "	36–40	—
6 "	41–45	—
1 "	46–50	—
1 "	51–55	—
1 "	56–60	—
(b)[3] 7 "	—	1.0
16 "	—	1.3
14 "	—	1.7
24 "	—	2.0
7 "	—	2.3
2 "	—	2.7
3 "	—	3.0

[1]In 1940 the hopperburn data were taken in three classes of injury: 1 light, 2 medium, 3 heavy.

[2]Difference between means of nymph counts required for significance at the 5-per cent level is 17.9, and for hopperburn .73.

[3]The group of 73 seedlings is distributed according to (a) number of nymphs and (b) amount of hopperburn.

showed just as much injury; and Nonesuch, with a mean of only 13.3 nymphs, was as severely injured as Irish Cobbler. On the other hand, Sequoia and Blue Salad showed relatively high nymph counts but were only slightly injured. There might be a correlation between number of nymphs and hopperburn on susceptible varieties, but in a group in which tolerant varieties predominate, as is shown in table 6, the correlation did not reach the 5-per cent level of significance.

The difference between hopperburn means required for significance at the 5-per cent level is 73. With this as the criterion, Sebago, Sequoia, Katahdin, Rural New Yorker No. 2, Blue Salad, and 61 of the seedlings were significantly less injured than Irish Cobbler, Warba, Red Warba, Bliss Triumph, Earlaine, and Pontiac. Among the commercial varieties, Katahdin, Sebago, Sequoia, and Rural New Yorker No. 2 showed some resistance. The Rural New Yorker No. 2 was not so heavily infested with nymphs as the Sequoia, but the mean hopperburn injury for both was the same.

DISCUSSION

The data obtained on hopperburn resistance are difficult to interpret genetically. This is due, in part, to the fact that the test did not include progenies with parents highly susceptible to leafhopper injury, and partly to the wide variations caused by conditions under which the tests were made.

The interactions of genetic and environmental factors are plainly discernible, however, but how many of each are involved in the various seedling progeny reactions is a question. From the breeding standpoint, many seedlings have been selected showing a high degree of resistance or tolerance. In some cases the escape may be caused by the fact that the leafhoppers do not infest them so heavily; in others, there is definite tolerance, for regardless of the number of nymphs per leaf very little injury results.

Other observations made during the progress of these tests are important. If hopperburn and a disease such as late blight occur together, it is difficult to determine the damage caused by each, and as a result one or the other may not be charged with its proper share of the damage. Plants infected with virus diseases, such as rugose mosaic, leafroll, or spindle tuber, suffer more from hopperburn than do healthy plants of the same clonal line.

Some of the injury that has been attributed to heat and drought

is no doubt caused by leafhopper injury, and, conversely, some of the heat and drought resistance that has been reported is due in part to hopperburn tolerance and has been pointed out before by Allen and Rieman (1).

There seems to be a correlation between earliness and susceptibility in some groups, but this again may be a pseudo-relationship, since it is difficult to distinguish between necrosis caused by maturity and that caused by leafhoppers.

Many of the seedlings selected for a period of years have been commercially resistant, but none of them is immune. If immunity is desired, hybrids between such species as *Solanum polyadenium* and commercial varieties probably will have to be used.

SUMMARY

A number of progenies segregated for various degrees of resistance and of tolerance to the potato leafhopper.

Of 14 progenies tested three showed a small but significant positive correlation, and one showed a negative correlation between resistance to late blight and resistance to attack by the potato leafhopper.

Nymphal populations were significantly larger on some seedlings than on others. Correlations calculated between nymphal populations in 1938 and 1939 on 5 progenies did not reach the 5 per cent level of significance.

The correlations between nymphal populations and the degrees of hopperburn, with one exception, were not significant. This fact indicates that the variations between seedlings as to the amount of hopperburn were not because of differences in leafhopper populations.

The analysis of the 1940 data shows that there were highly significant differences between the varieties and seedlings in nymphal populations and in the amount of hopperburn. Sebago, Sequoia, Katahdin, Rural New Yorker No. 2, and 61 numbered seedlings were significantly more resistant to the potato leafhopper than Irish Cobbler, Warba, Red Warba, Bliss Triumph, Earlaine, and Pontiac.

A number of the seedlings were much more resistant and some were more tolerant to attack by the potato leafhopper than were any of the old commercial varieties.

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SECTIONAL NOTES

CALIFORNIA

A careful check of the remaining acreage in the Delta Section—San Joaquin County, California, on the 1st of October showed approximately 5,000 acres remaining unharvested.

A large percentage of this acreage was, comparatively speaking, late planting, and consequently, the yields will not be so heavy as those from the earlier plantings. The total crop produced from these 5,000 acres is estimated at approximately 3,000 cars—rail and truck shipments combined. The quality, promises to be very good.

The demand for potatoes this season has been very heavy in California, both for local consumption on account of the increased buying power of the public, and also for Army Camps and Navy Supply ships.

Our growers have adopted a very strong attitude on the market. The feeling is that as soon as the potatoes in the principal late potato sections are harvested and stored, the tone of the market will strengthen immediately, therefore considerably higher prices are anticipated for the balance of the season. (Oct. 4).—E. MARX.

One hundred and twenty-five acres of the White Rose variety passed final field inspection, and I assume that practically this same amount of Russets has passed the final inspection. A small acreage of Burbanks has also passed. These potatoes are being produced in northern California and the yield will probably average 225 sacks to the acre.

In addition to the potatoes that are being certified, the Kern County Seed Potato Association is again conducting its own inspection service to procure good seed potatoes. We are inspecting approximately 1,000 acres of White Rose potatoes that are being grown for seed also, and the yields will probably not only average 250 sacks per acre but also the quality will be very good. (Oct. 6.)—T. H. HANKINS.

This year approximately 32,000 acres of potatoes will be produced, the last of which will be harvested in a few days. Some of the potatoes that are now being harvested will be used for seed.

If the sugar beet program is not in operation in 1942 this county will probably reduce its acreage of potatoes from approximately 3,000 to 6,000 acres below that of 1941. Had it not been for the sugar beet program, this situation might have occurred during the season of 1941. (Oct. 7).—M. A. LINDSAY.

COLORADO

The past season in Colorado has been one of those "freakish" ones. The winter snowfall was above normal, so that an adequate supply of irrigation was assured and prospects were bright. All tests conducted by the Colorado Experiment Station over a period of five years have shown that the best planting dates in the Mountain Districts cover the period from the 18th to the 25th of May, and in the plains area, between the 5th and the 25th of June, so that our growers did not hasten their planting operations. Untimely rains and cold weather, however, delayed planting considerably beyond these optimum dates. The emergence was slow, and our stands were considerably below normal. Rains and cool weather continued throughout the season. This resulted in an early appearance of Early Blight throughout the state, some plantings in North-

ern Colorado being completely killed by the time they were 70 days old. An early frost on the 8th of September killed the vines in nearly all districts. It is estimated that the low temperature at this time reduced the crop by 2500 cars in the San Luis Valley or caused a reduction of 25 per cent and this average is about the same for the rest of the state. The set of tubers was unusually heavy so that the sizes will run mostly small to medium, with practically no large sizes or oversizes in the state. The San Luis Valley has better quality than it has had for the past two or three years, whereas Northern Colorado has more flea beetle damage than it has had for several years. It is interesting to know that the Katahdin seems to have less worm tracks than the other varieties grown in the district.

The certified seed crop will be somewhat smaller than last year's record production, because of lighter yields and more rejections—mainly because of virus diseases. The cool season provided excellent conditions for reading mosaic and the tolerance for this disease had also been lowered.

Ring rot in the certified seed seems to be well under control and very few lots were rejected this year because of this disease. Considerable ring rot has, however, been found in table stock and an intensive campaign is being conducted to eliminate it. (Oct. 10).—C. H. METZGER.

MICHIGAN

Late growing conditions were favorable in Michigan and our yields are somewhat higher than we predicted during September.

Our harvesting is nearly finished, with some sections digging green vines, there being no killing frost to date. The quality is exceptionally good with large-sized tubers.

The certified seed acreage that passed final field inspection is slightly above that of 1940. However, the yields are somewhat lower which will probably result in Michigan's final report of certified seed being slightly under that of last year. (Oct. 13).—H. A. REILEY.

MINNESOTA

Excessive fall rains have delayed harvesting operations at least two weeks but the operation is now nearly completed.

Weather conditions during the growing season were very spotty, with the result that very good yields are reported from some areas, whereas in others the yields will be less than in 1940.

Eighteen thousand one hundred and thirty-five (18,135) acres were inspected for certification this year. This shows an increase of 2400 more than in 1940, and the final acreage passed for certification was likewise increased in proportion. The increased acreage this year consists of Irish Cobbler, Bliss Triumph, and Red Warba varieties. (Oct. 10).—A. G. TOLAAS.

NEBRASKA

Intermittent showers and cold weather have delayed our digging operations in the Panhandle Section of Nebraska during the past week. Our harvesting operations began earlier than usual, because of an extremely early frost that attacked most of the fields on the 8th of September. This frost was two to three weeks earlier than is generally experienced. In fact, for the last three seasons, frost has held off until the latter part of October.

This early frost was the culmination of a series of unfavorable circumstances affecting the main potato crop in Nebraska. The season began very favorably, with ample rainfall and cool weather during June and the early part of July, which resulted in a rapid growth. Even though planting had been delayed a week to ten days because of rain, by the middle of July the crop was equal to, if not better than, it usually was at that time of the year. The latter part of July and early part of August were extremely hot, with no rainfall, and excessive firing and tip burn took place. Tubers which had formed during the cool period were retarded in growth and remained dormant in the ground during that period. About the third week in August, general rains and cool weather again came, and the potatoes on dry land fields resumed growth. Continued rainfall during this latter period resulted in Early Blight developing fairly rapidly. Many fields were practically mature by the fifth of September, and practically all except the latest-planted potatoes were somewhat affected.

The result of this peculiar set of conditions was that considerable second growth developed, and the quality was not nearly so good as it has been in past seasons. The early frost, limiting the growing season, by two or three weeks, has materially reduced the yields, as well. The very best yields under irrigation reported to date, are slightly in excess of 300 bushels per acre, and many will be in the neighborhood of 200, whereas we usually expect to double those yields. In the case of the dry land fields, the yields will range between 50 and 125 bushels per acre, and the quality will probably be the same in both the dry and the irrigated sections. Our growers, as a whole, are somewhat pessimistic

concerning the situation—particularly regarding the general quality and yield.

The prices, at the present time, range from 45 cents to 50 cents per hundredweight, without sacks, to the grower, at the end of the washer. Certified potatoes will be sold on future contract at $1.35 per cwt. (Oct. 10).—MARX KOEHNKE.

OHIO

The crop estimate on the 10th of October shows that Ohio has an additional three-fourths of a million bushels of potatoes compared with last season. The early crop yielded exceptionally well and many 400-bushel yields have been ported. Most of this increase has been due to the excellent yields of the early crop since the late crop will be short.

The marketing season reached its peak about two weeks ago and is now beginning to decline, and out-of-state potatoes will soon be needed in Ohio. Recently prices advanced 1 cent a peck and 10 cents per hundred pounds. A large volume has been marketed through the State Potato Marketing Association. Prices through this Association have been above those received by most individual growers. (Oct. 15).—EARL B. TUSSING.

OREGON

The Klamath crop is not nearly so large as that of last year—the acreage being decreased nearly 10 per cent and the yields from 20 to 25 per cent below the yields that prevailed last year. Harvesting is getting started in good shape, with normal shipments and considerable storage at the present time. The quality, in general, is good.

The quality of certified seed potatoes seems to be a little above that of a year ago, with less diseases prevalent to date. Our acreage of certified seed is also a little greater than that of both the White Rose and the Russets. (Oct. 7).—C. A. HENDERSON.

PENNSYLVANIA

Climatic conditions during the past month have been very dry, and for short periods, quite hot. Most of the plants in the seed fields died earlier than usual, because of the lack of moisture. This, however, caused the tubers to retain a size that will grade out most economically. The crop that is being harvested is in a bright and smooth condition, with very little soil adhering to the tubers. Although there is some

scab prevalent on the Katahdins and Houmas, as a whole, there appears to be less scab infection than usual.

In the Potter County area where there was a liberal amount of moisture during the growing season, late blight tuber rot is being found, although the losses caused by this rot are negligible.

A special digging inspection for Bacterial Ring-rot is being made, in the certified seed fields. Several fields have been found to be infected, but the distribution of the disease through the seed crop is even less than was anticipated. All fields that were found to be infected with the disease are being rejected.

Our yields this season are running about average, or possibly slightly above for all the early and medium late-maturing varieties. Nittany, Cobblers, Chippewas, Houmas, and Katahdins are producing some excellent seed crops. Yields on the Russet and White Rurals are below average, and, in some cases, are running below Katahdins. (Oct. 10). —K. W. LAUER.

RHODE ISLAND

The yields of Cobblers were generally light because of the dry weather in May and June. A few growers on the heavier soil types reported a very satisfactory crop. The late crop is generally good. Some growers report higher than average yields. The quality is excellent, and a number of fields planted with the Sebago variety are producing very fine yields. A few fields of this variety have shown considerable black leg which may apparently be traced to the seed. At present our prices are strengthening—the Green Mountains selling at $1.65 to $1.75 per cwt. (Oct. 14).—T. E. ODLAND.

VERMONT

Approximately 40,000 bushels have been produced by Fred W. Peaslee of Guildhall—Vermont's largest grower in 1941. They were grown on 115 acres of Connecticut River land, and consisted of the Green Mountain and Houma varieties. Forty acres were entered and passed certification. This year, a total of 346 acres of seed potatoes were certified.

The digging season, practically completed on the 15th of October showed little late blight rot in seed and commercial fields, but a large percentage was prevalent in home-use lots where spraying was neglected. Bacterial ring rot has been found in only three lots, to date—two cases being traced to previously known infection.

The shortage of paper bags for peck packs is causing difficulties for several larger growers who have developed a market for such packages. (Oct. 10).—HAROLD L. BAILEY.

WASHINGTON

Generally speaking, the quality of certified seed potatoes should be superior to that of last year, because of conditions that have lent themselves to more efficient roguing throughout the growing season. The acreage has been greatly reduced this season, and a few weeks of hot dry weather in the early fall prematurely killed the plants, although it did not affect the yields materially.

Late blight has been prevalent throughout the season, and as digging operations proceed, we find it to be more severe than our earlier expectations. Fields have been showing considerable tuber infection, with the probability that more will be observed after the potatoes have been in storage for several weeks.

Although final inspections have been made on the White Rose variety, and the harvesting is proceeding as fast as the weather will permit, we find that only a small proportion of the seed has been disposed of to date. There have been only two shipments of certified White Rose sent to South America. The commercial market, having been very weak for the past month, has picked up, and the farmers are again making large shipments to Hawaii and to our numerous army camps. (Oct. 7).—HERB PICKARD.

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THE CONTROL OF POTATO APHIDS ON LONG ISLAND

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Potato plantings on Long Island are occasionally heavily infested with several species of aphids, primarily the pink and green aphid, *Macrosiphum solanifolii* (Ashm), and the green peach aphid, *Mysus persicae* (Sulzer). At the peak of infestation of a severe outbreak it is not uncommon for populations of these aphids to number several thousands on an individual potato plant. The injury resulting from the feeding of so large a number of aphids appears usually as a retardation of terminal growth, leaflet curl and premature drop of the lower, older leaves (Fig. 1). It seems obvious that such damage to the plant foliage during the time of rapid tuber development should be reflected in the yield of potatoes.

Previous experiments conducted for several years on Long Island have indicated that the control of aphids was not warranted because the small yield increases were not always commensurate with the cost of treatment. This is the conclusion of Huckett (2) in the summation of experimental work conducted around the North Fork area during a five-year period[1] Simpson (3) and Dickison (1) concluded from later experiments that in-as-much as tuber yields were not increased by control measures, potato aphids caused little or no damage to the "table stock" crop. Consequently, potato growers have been inclined to overlook heavy aphid infestations and to minimize the attendant damage, as a result that control practices have not been adopted.

[1]The writers wish to express their gratitude to Mr. G. W. Leonard, Dr. R. B. Arnold, Wm. Ralston, and Dr. J. F. Alsterlund of the Tobacco By-Products and Chemical Corporation for material, and equipment and also for collaboration in various phases of the work.

FIGURE 1.—Aphid injury to potato foliage. Note the curled leaves and the dead terminals.

EXPERIMENTS IN 1939

An experiment in 1939 for a comparison of various insecticides in the potato spray program, gave definite indications of yield increases from aphid control although growing conditions were unfavorable and tuber yields abnormally low.

In table 1 are listed the sprays tested and the insect populations taken from the various sprayed and unsprayed plots. A low lime bordeaux spray was compared with an insoluble copper, yellow cuprous oxide, to which was added in one case, sulfur dust, pyrethrum and rotenone-bearing powders. The spray materials of the infestation schedule were varied to correspond with the particular insect problem at hand. Nicotine sulfate was used for aphid control.

When the insect data (Table 1) were examined and correlated with tuber yields, the only significant correlation was between potato aphid populations and yields. Treatments which decreased the numbers of aphids increased yields. On the other hand, treatments which increased aphids decreased yields as in the instances of bordeaux and yellow cuprous oxide when used without insecticides.

TABLE 1.—*A comparison of several potato sprays on the control of insects and the resultant effect on tuber yields.*

Treatment	Yield (Bu. per acre)	Aphids	Leafhoppers	Flea Beetles
Bordeaux 4-2-50	166.8	19,354	69	390
Yellow cuprous oxide and talc	170.5	15,066	77	509
Unsprayed	182.5	10,557	218	559
Infestation schedule using Nicotine for aphids	191.3	7,057	270	399
Yellow cuprous oxide, sulfur, pyrethrum and rotenone powders	204.0	3,304	108	579
Least difference for significance				
5 per cent	20.3			
1 per cent	28.3			

EXPERIMENTS IN 1940

Our attempts to control aphids and to measure the effect on yields were continued during the 1940 summer season which in contrast to 1939 was a very favorable period for the development of the crop. An outbreak of aphids occurred as in the previous year and fortunately was not accompanied by a damaging number of other potato insects the control of which makes it difficult to delineate the value of aphid reduction. Late blight was serious during the latter part of the growing season and caused considerable tuber rot in one experiment because of inadequate foliage protection.

Two methods were used in 1940 for the control of aphids, a nicotine spray and nicotine vapor fumigation. Spray applications were

made with a tractor-powered sprayer using 400 pounds pressure and a spray delivery of 175 gallons to the acre. The applications were, therefore, very thorough to insure a good aphid kill. Nicotine sulfate was added to the 4-2-50 bordeaux mixture at a 1-400 concentration and 3/8 of a pound of sodium lauryl sulfate was used to each 100 gallons of spray.

In two additional experiments, the aphids were controlled by means of the "Nicotine Vaporizer." This machine vaporizes a highly concentrated specially compounded product containing 80 per cent nicotine. The vapor is released under a light weight, specially designed 100-foot canvas trailer which is drawn over six rows of potatoes at the rate of 100 feet a minute. Essentially a field fumigation is obtained in a restricted moving chamber, using a high concentration of insecticide for a short exposure.

An estimate of the efficiencies of the treatments was obtained by three methods; (1) by sweeping with an insect net, (2) beating the foliage above a tin collecting pan and (3) counting the aphids on leaflet samples.

Sweeping data indicated a lower per cent of aphids killed than the other two methods because of the fact that many dead aphids were clinging to the foliage at the time of sampling. When taking the sweepings these dead aphids were collected as part of the population sample. The sample was preserved in alcohol and counted at a later date. It was then impossible to discount the number of dead aphids from the population. Leaflet samples, which were counted in the field, probably gave a better estimate of the efficiency of the treatments than the sweeping samples.

The effectiveness of the nicotine spray in decreasing the aphids and the resultant increase in tuber yields are shown in table 2. Differences in the conditions of the foliage, although not striking at any time, were soon apparent after the applications were made. In the plots sprayed only with bordeaux, the leaves were dwarfed and rolled, and the growing tips were killed. By reducing the aphid populations with the addition of nicotine sulfate to the bordeaux, aphid injury was greatly reduced. It is evident from the data recorded that aphid control was reflected in increased yields of potatoes. Because of a late blight infection no unsprayed plots were left for comparison with the sprayed plots.

The work with the "Nicotine vaporizer" consisted of two timing experiments, using in one instance a field of the early-maturing Cobbler variety, and in the other case a field of Green Mountain potatoes. These experiments were designed to determine the benefits in terms of yield

TABLE 2.—*The effect of the addition of nicotine sulfate to bordeaux mixture on potato aphid populations and tuber yields of Green Mountain potatoes*

Treatment	Aphid Populations				Yields	
	Sweeping Counts	Per cent Control	Leaflet Counts	Per cent Control	Bus. per Acre	Increase
Bordeaux plus nicotine	1,802	70.1	34	92.6	385.8	59.9
Bordeaux alone	6,023		459		325.9	
Least difference to be significant						
5 per cent	1,253		170		25.7	
1 per cent	1,733		239		35.6	

increases of making one or more fumigations during the aphid period which lasts approximately three weeks. Originally, it had been intended to compare (1) three successive weekly applications of nicotine vapor starting a few days previous to the peak of aphid abundance; (2) two successive fumigations starting at the peak; and (3) a single application several days past the peak. However, it was not possible to make the early fumigation and only two applications were made, one on the 10th of July and one on the 18th. On the 10th, the peak of aphid population had been reached and by the 18th the numbers of aphids had declined considerably.

Data from these experiments have shown excellent kills with the use of nicotine vapor and significant increases in the tuber yields. Applications made on the 10th of July were more important than those made on the 18th. Furthermore, two successive fumigations increased the yields no more than the single fumigation made on the 10th of July.

TABLE 3.—*The control of potato aphids by nicotine fumigation in two experiments.*

Treatment	Cobbler Variety		Green Mountain Variety	
	Number of Aphids	Per cent Control	Number of Aphids	Per cent Control
Fumigated	96	97.1	160	87.5
Untreated	3,360		1,328	

TABLE 4.—*Increases in yields of potatoes from control of aphids by nicotine fumigation.*

Dates of Fumigation	Cobbler Variety		Green Mountain Variety	
	Yield Bus. 1 Acre	Increase over Untreated	Yield Bus. 1 Acre	Increase over Untreated
July 10 and 18	440.7	39.0	320.0	50.0
July 10	432.2	30.5	328.9	58.9
July 18	414.5	12.8	284.0	14.1
Untreated	401.7		270.0	
Least difference 5 per cent		20.5		17.3
to be significant 1 per cent		29.4		24.8

YIELD DECREASES BY BORDEAUX SPRAY

For a number of years it has been noticed that aphids are more numerous on potatotes sprayed with bordeaux than on unsprayed plants. Data from ten spray experiments conducted in Nassau County and covering a five-year period have shown an average increase in aphids of approximately 50 per cent for the bordeaux-sprayed plants.

Furthermore it has not been uncommon to obtain decreases in yield from bordeaux spraying as illustrated in table 1. In ten non-blight years 23 spray experiments, from a total of 36 performed have shown that bordeaux-sprayed plants yielded less than the untreated plants by approximately 17 bushels per acre. The range of these decreases has been from 1.7 bushels to 46.6 bushels per acre. Despite the fact that flea beetles and leafhoppers are at least partially controlled by bordeaux, spraying has been unprofitable during most seasons when late blight has not been epidemic.

The reason for such yield decreases has not been definitely established. The work of Wilson and Runnels (4) showed that Bordeaux spray increased transpiration. An increase in the water loss from the foliage might cause a decrease in tuber yields during seasons of deficient rainfall. No excessive wilting of sprayed potatoes has been noticed in the experimental plots on Long Island even when the soil moisture was low.

Continued spraying with Bordeaux of successive crops in the same fields may have increased the copper content of the soil for a period of years but evidence that this copper has a depressing effect on growth has not been convincing.

The field experiments of 1939 and 1940 form a basis for an explanation of the decreases in yields from potatoes sprayed with bordeaux mixture The substantial increase in aphid populations following Bordeaux spray applications appeared to damage the potatoes sufficiently to lower the yield on sprayed potatoes. This increase in aphid injury during heavy infestations more than offset the benefits derived from the control of flea beetles and leafhoppers by the bordeaux spray. Further experiments will be necessary before the rôle of aphids can be established as a factor in decreasing yields which has been attributed to bordeaux "injury."

Summary

Potato aphids, *Macrosiphum solanifolii* Ashm. and *Myzus persicae* Sulz. have frequently infested Long Island potato plantings. The use of nicotine spray and nicotine vapor has given excellent control of potato aphids which has been reflected in increased yields of tubers.

For a number of years observations have shown that the potato aphid populations at the peak of infestation are larger on bordeaux-sprayed plants than on unsprayed plants. Furthermore bordeaux spraying has in many instances, decreased yields during non-blight years. The increased aphid populations on bordeaux-sprayed plants may account for these decreases in yield.

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EFFECT OF SULFUR AND LIMESTONE SOIL TREATMENTS ON POTATO SCAB IN A SANDY SOIL

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Common scab (*Actinomyces scabies* (Thax.) Güssow) has caused great losses of potatoes at Arcadia, Florida, in fields of Leon fine sand, prairie phase, where successive crops have been grown from untreated seed. In fact, some fields in this area have been abandoned for potato culture because over one-fourth of the tubers of the third crop were made unmarketable by scab. On the other hand, scab has caused very little loss at Hastings, Florida, where untreated seed potatoes have been planted for as many as twenty-five years in succession in Bladen, Leon, Scranton, Plummer, Portsmouth and St. Johns types of sandy soils. During this period the severity of the disease has increased very little in any of these fields.

From 1938 to 1941, experiments were conducted at Arcadia, Florida, in a field of Leon fine sand, prairie phase, which had become severely infested with the scab organism, to determine if soil treatments with sulfur and limestone would control scab. Results of these experiments are reported herein.

Materials and Methods

The type of soil used in these experiments consisted of Leon fine sand, prairie phase, which occurs in Florida near swamps and fresh water marsh land within a radius of 125 miles of Lake Okeechobee (5). This soil is used mostly for grazing but when properly drained, cultivated, fertilized and irrigated, it will produce excellent yields of truck crops. The plots were situated in two blocks of this soil in which two crops of potatoes had been grown.

The soil treatments consisted of applications of different quantities of commercial flowers of sulfur and 80-mesh, ground limestone. These agents were applied to plowed land by broadcasting in 1938 and with a lime distributor in 1939 and thoroughly incorporated with the soil by several diskings.

[1]Thanks are due Mr. Dale Foster, Arcadia, Florida, for supplying land and farming equipment used in these experiments.

In block 1, the plots were 100 by 30 feet and those treated with sulfur on the 24th of May 1938 were divided into halves lengthwise, of which one-half was treated with limestone two months later. (Table 1). In block 2, plots were 640 by 21 feet and 3 of those that were sulfured on the 30th of May, 1939, were treated with limestone 4½ months later.

Soil pH readings were made at different times from composite samples drawn from the upper 6 to 8 inches of soil in the various plots.

The seed potatoes used in planting the plots were given the hot formaldehyde treatment for scab control before they were cut for planting.

Scab readings were based upon the number of tubers affected with the disease in a random sample of tubers taken from the center row of each plot. Each sample in block 1 consisted of 100 to 200 tubers and in block 2, 350 to 400 tubers. These tubers were sorted into two classes. The first class consisted of tubers free from scab lesions, and other marketable tubers that showed only a few small scab lesions. The second class included all scabby tubers which could not be classified as salable primes or seconds (10).

Results

Scab was severe on potatoes grown in non-treated soil for the first three years (1938-1940). The disease was mild in 1941 but this does not mean that it is permanently disappearing from the field because scab, like other diseases, may fluctuate in severity from year to year, depending upon whether or not soil and climatic factors favor its development (2, 4).

The soil was made more acid and the percentage of tubers affected with scab was greatly reduced in all plots treated with sulfur at the rates of 400 pounds to 1200 pounds per acre, as shown in table 1. The yield data obtained from the treated and non-treated plots, which were not replicated, are not considered suitable for statistical analysis. However, the effect of the sulfur in stunting the growth of potato plants and in reducing their yields was apparent (1, 2, 3).

When Bladen, Scranton and Leon sandy soils were treated with 400 pounds to 800 pounds of sulfur per acre at Hastings, Florida, potato yields were reduced 17 per cent to 93.5 per cent the first year. Furthermore after treatment, 3 to 5 years elapsed before these soils were naturally re-adjusted to normal pH reactions and their productivity restored (1, 2, 3). The reaction of Leon fine sand, prairie phase, to sulfur treat-

TABLE 1.—*Effect of soil treatments with sulfur and limestone following sulfur upon the soil reaction and scab infection in 4 crops of potatoes grown in Leon Fine Sand, Prairie Phase, at Arcadia, Florida, from 1938 to 1940.**

Treatment (Pounds per Acre)	Soil pH before Treating	Soil pH at Harvest	Per cent Scabby Tubers**	Soil pH at Harvest	Per cent Scabby Tubers**
Block 1. Sulfur Applied 5/24/38 and Limestone 7/19/38.					
	1938	1938	1938	1939	1939
None	5.7	5.5	18	5.5	43.2
400 Sulfur		4.6	2	4.5	6.0
400 Sulfur 3000 Limestone		4.8	12	5.3	42.4
None	5.4	5.3	51	5.1	68.4
600 Sulfur		4.6	8	4.7	1.8
600 Sulfur 3000 Limestone		5.4	4	5.1	14.5
None	5.3	5.5	21	5.4	29.4
800 Sulfur		4.5	0	4.8	9.2
800 Sulfur 3000 Limestone		5.6	6	5.5	0.0
Block 2. Sulfur Applied 5/30/39 and Limestone 10/19/39.					
	1939	1940	1940	1941	1941
None	6.2	5.3	59.5	5.2	8.9
800 Sulfur	6.1	4.3	3.9	5.1	0.6
800 Sulfur 1500 Limestone	6.1	4.8	12.5	5.5	1.7
None	Not Read	5.4	45.8	5.6	10.9
1000 Sulfur	6.2	4.4	13.3	5.2	4.8
1000 Sulfur 2000 Limestone	6.2	5.8	32.0	5.8	19.3
None	5.9	5.2	45.3	5.6	6.6
1200 Sulfur	6.1	4.2	9.4	5.2	0.4
1200 Sulfur 3000 Limestone	6.1	6.0	31.3	6.0	39.1

*One crop of potatoes was grown in the fall and winter of 1938 and the other 3 crops in the winter and spring of 1939, 1940 and 1941.
**Not salable.

ment at Arcadia is similar to that of Leon and other sandy types at Hastings; consequently, the benefit obtained from controlling scab by sulfur treatment may be nullified by the loss in yield of potatoes caused by the treatments (7, 8, 9).

Plots were treated between potato crops with different quantities of sulfur and limestone to determine if the causal organism could be killed with sulfur during the summer, and yields restored without recovering the scab by treating the sulfured soil with limestone in the fall (3). The data in table 1 show that the disease was partially controlled by the sulfur-limestone treatment in the first crop of potatoes grown in the treated soil. However, in the second crop, scab increased in all with the exception of one of the treated plots in block 1, and there was actually more scab in two of the treated plots of block 2 than in the non-treated check plots.

In 1938, the least amount of scab was found in the Leon fine sand, prairie phase, in those areas where minimum reactions of pH 4.0 and lower were created by sulfuring the land, and most severe scab was found in the treated and non-treated areas where the minimum reactions were pH 5.0 and higher. In 1940, in certain areas of block 2 of the experimental plots where soil reactions varied from pH 4.0 to 4.8 at harvest time, 0.0 to 35.1 per cent of the tubers were affected with scab; whereas, in other areas with reactions of pH 5.2 to 5.7, 32.6 to 90.9 per cent of the tubers were affected with scab.

At Hastings, where seed potatoes are never treated, scab is generally mild and sporadic in occurrence in Bladen, Scranton and Leon soils with reactions of pH 4.4 to 6.5 (3); whereas, at Arcadia in Leon fine sand, prairie phase, testing pH 5.2 to 6.8, potatoes became severely affected with scab from planting two crops with untreated seed. Apparently, other factors besides pH reaction influence the occurrence of scab in the same and different soils (4, 6).

In 1939, seed potatoes which had been given the hot formaldehyde treatment for scab control were planted in untreated Leon fine sand, prairie phase, where 1, 2 and 3 crops, respectively, of potatoes had been grown from untreated seed. The percentage of severely scabbed tubers in the second, third and fourth crops of potatoes grown that year was 17.6 per cent, 25.6 per cent and 51.6 per cent respectively. In 1940, 50.2 per cent of the tubers of the fifth crop were severely scabbed; but, in 1941, when conditions were less favorable for scab, only 8.8 per cent of the tubers of the sixth crop were affected with the disease.

Conclusions

Scab was greatly reduced in infested Leon fine sand, prairie phase, by treating with sulfur, but the pH reactions established were not suitable for the best growth of potatoes. Consequently, the advantages of controlling the disease by such a treatment may be nullified by loss in yield of potatoes grown in the sulfured soil.

Scab was also reduced but not eliminated from the first crop of potatoes grown in soil which had been treated with both sulfur and limestone between potato crops. This treatment does not appear practicable either, for the disease increased the second year and was almost as severe on potatoes grown in the treated land as in those grown in nontreated land.

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POTATO BREEDING, GENETICS, AND CYTOLOGY: REVIEW OF LITERATURE, 1940[1]

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The review of literature for the 1940 report of the Potato Association of America covers a relatively wide range of subjects. Many of these subjects have been discussed in papers previously reported. All the papers reported here show progress, and a few of them describe new features that should be interesting to potato growers and research workers. Emphasis is being given to obtaining varieties suited to particular sets of environmental conditions. This will tend to increase the number of varieties grown commercially in the United States. Those who think there are now too many varieties can perhaps take comfort from the fact that the little country of Scotland has at present about one hundred, and seems to be making progress in potato production.

Varieties differ in cultural requirements, and, as is pointed out by McIntosh (19), growers should study their individual characteristics and treat them accordingly.

The features discussed in the papers that should be of especial interest to research workers include:

(1) Breeding methods: Some of the effects of inbreeding and the production of self-fertile lines.

(2) Tuber quality.

(3) Immunity in the field to viruses X, A, B, or C, and resistance in the greenhouse and field to Y.

(4) Further evidences of resistance to leafroll.

(5) Resistance to tuber rot initiated by late blight—one of the most important characters yet brought to light.

(6) The production of early scab-resistant varieties. Heretofore the best scab-resistant sorts were late.

(7) Resistance to Fusaria in the field.

(8) Resistance to Colorado beetle and to eelworm.

(9) Haploid plants.

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[1]Much of the material in this report, especially that concerning articles written in foreign languages, was taken from the abstracts published by the Imperial Bureau of Plant Genetics, Cambridge, England.

[2]Senior Geneticist.

VARIETIES

McIntosh (19) reported that there are about 100 cultivated varieties of potatoes in Scotland. In addition, there are a considerable number of rogue varieties which represent largely varieties that have dropped out of cultivation. The development of "wildings" and "bolters" is discussed with the suggestion that some of them develop as *periclinal* or as *sectorial chimaeras*.

As varieties differ in commercial and other characters, so do they differ in cultural requirements. A few varieties are widely adapted and do not require special consideration, but in regard to the majority of varieties, growers should study their individual characteristics and treat them accordingly.

Stevenson (37) gives an account of the behavior of fourteen varieties of potatoes that have been distributed recently to growers, and grown in a number of states. Chippewa, Houma, Katahdin, Sebago, and Sequoia have been promising under a comparatively wide range of conditions.

A brief outline of the work under the National Potato Breeding Program of the U. S. Department of Agriculture is given by Stevenson (34). Special emphasis is placed on the problems of breeding varieties resistant to virus diseases, late blight, and common scab. Immunity in the field to mild mosaic, and "field" and "graft" immunity to latent mosaic are heritable.

A relatively large number of seedlings have been produced with varying degrees of resistance to late blight. Sebago, a blight-resistant selection from the cross Chippewa x Katahdin, has been distributed to growers. Scab resistance behaves somewhat like a recessive character; lateness appears to behave as a dominant; and the problem of getting an early scab-resistant potato is not easy.

Stevenson (35) investigated the desirability of developing varieties of potatoes adapted to a particular environment, with stress on resistance to diseases. Some of the accomplishments in the field of disease resistance are cited to show the possibilities in that mode of attack.

Barabanov and Piunowski (3) made a study of new varieties in Russia. The variety Lorkh (Switez x Furstenkrone), which is said to be resistant to virus diseases and somewhat resistant to blight, is described. It is high in yield and the tubers are large and of high quality. The variety Kollektwnyi (Kriemhilde x Furstenkrone) is also described. It is a high-yielding commercial variety said to be resistant to virus.

Tussing (39) reported that six late potato seedlings obtained from the U. S. Department of Agriculture outyielded the Russet Rural stand-

ard variety in tests in Ohio. Seedling 47,101 appeared to be particularly desirable. The relative value of various potato varieties for the manufacture of potato chips is also given.

Mattson (20) emphasizes the fact that many potato varieties of commercial importance in other sections of the country are not suited to conditions in North Dakota, and the North Dakota Agricultural Experiment Station is attempting to produce varieties adapted to local conditions.

The methods used in the description and propagation of cultivated potatoes in Peru are given by Soukup (33). In addition, there is a key for the identification of 65 native Peruvian potato varieties from the Department of Puno, based mainly on tuber characters. This is followed by morphological descriptions of the varieties with illustrations of tubers and sprouts, and notes on the distribution and average yield, obtained at the Granja Salcedo, Puno, Peru.

The yield, quality, earliness, disease resistance, and keeping properties of numerous varieties and strains of potatoes in Swedish trials from 1914 to 1938 are discussed by Agerberg (1). A table indicates the most important features and some identification characters of the varieties. Eigenheimer has been the outstanding variety in these tests. It has surpassed most of the others in yield and all in percentage of starch and dry-matter content. Its flavor is excellent and keeping quality satisfactory if given suitable storage conditions. It is quite early. Wekaragis is recommended as a wart-resistant type suited for stock food. It exceeded Eigenheimer in yield.

Salaman in England (29) reports on the potato expedition to South America organized by the Executive Council of the Imperial Agricultural Bureaus. Six hundred specimens from Central and South America, assembled at Cambridge, were being classified botanically, studied cytologically, and tested for resistance to two strains of *Phytophthora infestans* and other diseases. Many of the *Solanum demissum* types from Mexico were resistant to both forms of blight, but a few of them were susceptible to both. All the cultivated Peruvian varieties were susceptible, but a few South American species obtained from Russia were immune.

Methods

Guern (10) reported on self-pollinated strains of potatoes in Russia. A number of varieties, such as Peterson's Victoria and Early Rose, were among the commercial varieties mentioned as having been produced by selfing standard varieties, and special emphasis is laid on the possi-

bility of obtaining earlier maturing varieties by this method. Seedlings of the first selfed generation gave yields 20 to 40 per cent below plants of the parent line grown from tubers. Only 5 to 6 per cent of the total seedlings were fertile, and some varieties gave no fertile seedlings. Many dwarfs, chlorophyll deficiencies, and other aberrations occurred among the seedlings. The third and later generations were somewhat freer from these aberrant forms and slightly better in yield.

The proportion of fertile seedlings was distinctly higher in the third and later generations, and in the fifth and sixth as many as 80 per cent of the seedlings of some lines were fertile. Segregation continued even into the sixth and seventh generations, particularly in respect to tuber color. Hybrids between inbred lines were not equal in yield to the original material, but some relatively high-yielding seedlings were produced, some surpassing the standard variety in yield and some in earliness of tuber formation. The author expressed the view that almost any potato variety can be made fertile by selfing for five to six generations and that the present-day varieties are too heterozygous and would gain by a certain amount of inbreeding.

Potato Breeders

An account is given by Davidson (7) of the careers of potato breeders in Britain, both private and commercial, from the early days of cultivation of the crop to the present day. As far as they are known, the histories of the important varieties are given.

Tuber Quality

Attention is called by Stevenson (36) to the sources of variability in the cooking quality of potatoes and to some of the difficulties of any potato-breeding program resulting from such variability.

Standards for superior table quality are diverse. The characters that are combined in what is known as culinary quality are subject to variations from many sources. There are inherent differences in quality among varieties, but good quality is made or marred by environmental factors. As a result, a variety that produces tubers of excellent quality when grown under one set of conditions, may be poor in quality under others. Cooking and market quality can be improved by the best cultural practices, by allowing the crop to mature before harvest, and by careful grading and handling of the tubers after harvest.

Kroner and Schmalfuss in Germany (16) emphasize the import-

ance of producing potatoes which when sliced for drying and storing, do not turn dark. There are distinct differences among varieties with respect to this character. Certain varieties, such as Fruhgold, darken less readily and to a much less degree than others. Parnassia darkens readily and to a high degree.

Ostanin (23) reports from Russia that differences were found in the rate at which starch turned to sugar, though the differences among varieties, and even among species, were not very great. *S. andigenum* had a higher salt and phosphorus content than *S. tuberosum* varieties. Differences were observed in the refractive index of the starch solution, its viscosity, and the temperature of gelatinization.

Clark, Lombard, and Whiteman of the U. S. Department of Agriculture (6) investigated the cooking quality of the potato as measured by specific gravity. The determination of specific gravity by flotation in salt solutions of known density is a satisfactory method of selecting for mealiness among potato seedlings. Differences were found between tubers of the same variety grown in the same row, as well as between varieties. The tubers of some varieties varied much more than others. A significant interaction between season and mealiness indicates that the tests, to be reliable, should be made over a period of years.

Arnautov (2) reported differences in yield, earliness, and starch content in tubers grown under different conditions of fertility, and the findings are claimed to be contrary to Mendelian theory.

Stoloniferousness

Miller *et al* (21) made studies of the relation of some growth characters to the stoloniferous condition in seedling Irish potatoes. Several potato seedling progenies were studied with regard to stoloniferousness, and the data were correlated with those for degree of maturity, height of plant, maximum stolon length, and heat sprouting. The data for stolon development were taken in five classes, ranging from basal set to completely stoloniferous. Maximum height of plant and earliness of maturity were given as useful criteria for selecting high-yielding varieties for Louisiana conditions.

Graft Hybrids

Experiments in Russia were reported by Razurnov (26) in which the progeny of Solanum-Datura grafts were distinguished by longer dormancy, and greater resistance to degeneration than the controls. Other

experiments showed that the changes induced in *S. Antipoviczii* by grafting were transmitted to the second clonal generation, and seedlings from the first tuber-propagated generation obtained after grafting retain the same variations as those induced by grafting.

Colchicine Treatments

Johnstone working at Cornell University (14) studied chromosome doubling in potatoes induced by colchicine treatment. Somatic chromosome doubling was induced in Russet Rural, Golden, S 164-126, S 164-196, 13-4, and in the wild species *S. Jamesii* (2 n = 24), *S. chacoense* (2 n = 24), *S. bulbocastanum* (2 n = 24), *S. andigenum* (2 n = 48), and *S. neantipovichii* (2 n = 48).

In general, the tetraploids had larger stomata, larger pollen grains, wider, thicker leaflets, large flowers with larger, coarser floral parts, and a slower rate of development than the corresponding diploids. Observations of the colchicine-treated plants, which gave rise to polyploids, indicate that it is necessary to approach the lethal dosage in order to get doubling of an entire growing point. The most satisfactory method is to germinate the seed in an approximately 0.5 per cent aqueous solution of the drug at a temperature which insures rapid and even germination.

The tetraploids of *S. tuberosum* and *S. andigenum* (diploid = 48 somatic chromosomes) were dwarfed, thick-stemmed, very succulent, infertile, and deformed in various ways when compared with the diploid checks. This might support the hypothesis that these species are tetraploids already. The tetraploids of *S. Jamesii, S. chacoense,* and *S. bulbocastanum* were at least as large as their diploid checks, were quite fertile, showed no marked increase in succulence, and were not usually deformed.

Disease Resistance

Lunden of Norway (18) discusses the problems involved in breeding disease-resistant potatoes. Some of these are: varietal differences in resistance, various diseases and their casual organism, physiological specialization in fungi, methods of infection, disease-resistant potatoes from South America and Mexico and their use in potato breeding in various countries, and the factorial basis of resistance to certain diseases. The importance of a thorough understanding of the biology of the fungi concerned and of the potato plant is stressed, as well as need for close cooperation between the breeder and plant pathologist.

Resistance to Viruses

The Scottish Plant Breeding Station (32) has shown by examination of several thousand seedlings from virus-diseased potato plants that the viruses are not transmitted from parent to offspring through the seed. Varieties resistant to the Y virus have been found, and a very high degree of resistance to leafroll has been found in two varieties and in their first generation seedlings. Varieties which are hypersensitive to viruses X, A, B, or C are very valuable since they are field immune to these viruses.

Jones *et al* of the State College of Washington (15) report that practically all the viruses, both mottling and necrosis, found in the field prior to 1938 were due to the Y virus. A number of varieties became 100 per cent infected in one year; the Katahdin was only 35 per cent infected. In 1938 and 1939 seedlings were mechanically infected with the Y virus in the greenhouse. A high percentage of resistant seedlings were found in some hybrid progenies but in the field only family lines with Katahdin as one of the parents contained seedlings resistant to vein-banding. In 1938 and 1939 a new infection was observed, resulting from the curly-top virus of sugar beet, and it was thought that Katahdin and Katahdin progenies were more susceptible than some other varieties and lines.

Resistance to Late Blight

Bonde *et al,* (4) studied the resistance of certain potato varieties and seedling progenies to late blight in the tubers in Maine. A number of potato varieties and their progenies were tested for resistance to late blight (*Phytophthora infestans*) in both vines and tubers. The tubers of Paisley No. 2, President, 336-144, and 336-18 showed no infection while those of other varieties were badly damaged. Resistant tubers were found in the F_1 progenies from crosses between resistant and susceptible varieties. Vine resistance and resistance to tuber rot occurred together in relatively high percentages in certain progenies, but the two characters were not controlled by the same genetic factors. Tuber resistance depended to some extent on maturity. Young tubers of some varieties were susceptible when immature but resistant when mature. Resistance to tuber rot may be morphological in some cases, but apparently it is physiological in others, since the fungus grew very slowly in the infected tubers of some varieties. Propagating Phytophthora on resistant varieties failed to increase its virulence.

Reddick (27) reported from Cornell University on the problems encountered in breeding varieties of potatoes immune to late blight (*Phytophthora infestans*). This disease is found in Mexico, and it is in that country that resistant and immune potatoes, such as *S. demissum*, are found. By crossing *S. demissum* with cultivated varieties and repeated back-crossing to cultivated varieties, blight-resistant varieties with commercial promise have been obtained. In discussing the parasite, the author states that *P. infestans* never forms oospores in North America but persists from year to year in the vegetative condition. The virulence of the zoospores can be stepped up by passage through a resistant host. The higher level of virulence is not lost when the organism is cultured on a susceptible variety.

Pettersson (24) describes a new "humidity dish" method for testing the reactions of leaves of blight-resistant potatoes to blight infection. A series of nine reaction types under very humid conditions was found.

Resistance to Common Scab

Schlumberger (31) discusses the most promising scab-resistant varieties in Germany. Carnea may be regarded as practically immune, and Akebia as fairly resistant. Other promising varieties are Kamecke's 15/23, Kneden Nos. 2106 and 874, Lochow 31/201, Pfetten 39/39, and Nordost 38/31/6. The last-named is an early variety and therefore of considerable interest.

Investigations in Germany by Noll (22) on the biology and control of potato scab revealed that resistance to scab was negatively correlated with ability to form wound callus on surfaces of cut tubers. Resistant varieties showed little scab infection on the underground portions of the vines. Resistance was not correlated with russeting of tubers, length of the vegetation period, rate of growth of the tubers, pH of pulped tuber extract, or rate of growth of the pathogen on a tuber extract medium.

Resistance to Fusaria

Edmundson and Schaal (8) found that in Colorado both *Fusarium eumartii* and *F. oxysporum* cause wilt in potatoes. A relatively large number of seedlings have been tested for resistance to these parasites, and several of them have shown a high degree of resistance in the field.

Wart Resistance

Salaman in England (28) reports that an important line of work done at the Ormskirk Potato Research Station has been testing for resistance to wart disease. Through the Lord Derby Snell Memorial Medals, and the trials associated with them, the breeding of new varieties of potatoes has been encouraged. The potato work at the station has been abandoned since a reliable laboratory test of wart resistance has been developed.

Bjorling of Sweden (5) discusses the wart disease, its mode of attack, the absence of physiological specialization of the fungus, and the simple technique for testing resistance and increasing the reliability of the tests. Variability in sprout length of the tubers used in infection tests may result in unreliable data. It is suggested that tubers with sprouts of medium length (1 to 2 mm) should be used in wart disease tests. If this is done reliable results can be obtained on small samples, even as few as two or three tubers per variety.

Piekarski (25) reports that very few Polish potatoes are wart-resistant, and tests have been made of a number of varieties imported from Germany. Ackersegen is one of the most popular. The main defect of this variety is its lateness. Earlier maturing varieties are being tested. It is concluded that as earliness increases, susceptibility to wart disease and irregularity of yield increases. These tendencies should be overcome by breeding superior varieties.

Resistance to Animal Parasites

Schaper (30) reports that all domestic varieties of potatoes used in joint experiments by German and French research workers were susceptible to the Colorado potato beetle. A degree of resistance was found in the following varieties: Aal, Weltwunder, Condon, Frau, and Wohltmann. The Solanum species varied in reactions. *S. caldasii* and *S. commersonii* were definitely poisonous to the insects. Some varieties of *S. demissum* were resistant. Resistance was found also in *S. Jamesii, S. polyadenium,* and *S. Henryi.* Some races of *S. chacoense* were more resistant than others.

Many of the clonal lines from the cross *S. demissum* x *S. tuberosum* were resistant. Some selections from the cross *S. acaule* x *S. tuberosum*, both susceptible species, showed a high degree of resistance. A number of triple hybrids, *S. acaule* x *S. demissum* x *S. tuberosum,* were resistant. Twelve out of 136 clones of the hybrid *S. chacoense* x

S. tuberosum were resistant. The progenies from *S. tuberosum* x *S. andigenum* were nearly all susceptible; one, however, was quite resistant and gave a high yield of good tubers. Progenies from *S. tuberosum* x *S. tuberosum* were all susceptible; those from *S. polyadenium* x *S. Jamesii* were highly resistant. In all, 42 out of 215 hybrids proved resistant in the 1937 tests, and 143 out of 1,369 in the 1938 tests.

Trouvelot in France (38) discusses the present state of the researches on tuberous Solanum species resistant to Colorado beetle. *Solanum demissum* has such a high degree of resistance to the Colorado beetle that the insect cannot become established on the plants. F_1 hybrids of *S. demissum* x *S. tuberosum* inherit the resistance in varying degree. Some of them are about as resistant as the *demissum* parent. None of these F_1 hybrids is very productive. The back-crosses to *S. tuberosum* are usually less resistant, but the possibility of getting resistant varieties possessing other characters of commercial importance, appears to be not too remote.

Leiper (17) mentions that some of the potatoes collected in Mexico and South America on the expedition financed by the Council of the Imperial Agricultural Bureaus show considerable resistance to eelworm infection. The possibility of breeding resistant commercial varieties is indicated.

CYTOLOGY

Emme (9) reports from Germany that sixteen plants were raised from the cross *S. demissum* ($2n = 72$) x *S. tenuifilamentum* ($2n = 36$). Chromosome counts in six of the F_1 plants showed numbers varying from 50 to 60. In one short-lived seedling chromosome counts of 18, 19, 36, 75, and 76 were recorded. The seedlings varied in height, some being dwarfs, and in leaf dissection, pubescence, photoperiodic reaction, and shape of tubers. A cross between *S. phureja* ($2n = 24$) and the Colorado beetle-resisting species *S. Jamesii* ($2n = 24$) was also made and, although the reduction division in the hybrids was normal, no fruit was set. Hybrids were produced also from crosses between *S. gibberulosum, S. Knappei,* and *S. Schickii,* all 24-chromosome species.

Ivanovskaja of the U. S. R. R. (13) made a cytological study of *Solanum Millanii,* a wild frost-resistant potato from the Argentine. A number of meiotic irregularities were observed: univalents, bivalents, quadrivalents, bridges, etc. It was concluded that *S. Millanii* probably originated from an unreduced gamete of *S. chacoense* Bitt fertilized by a haploid gamete of a diploid species closely related to *S. chacoense*. *S.*

Millanii has 36 chromosomes and resembles *S. chacoense* in morphological characters.

Ivanov (11) reports from the U. S. S. R. that a hybrid formed by crossing the Phytophthora-resistant *S. Antipoviczii* ($2n = 48$) female with *S. tuberosum* variety Mirabilis ($2n = 48$) male was found to have 72 somatic chromosomes, indicating that one of the gametes was unreduced.

The resistant F_1 plant showed from 34-42, mostly 36-39, elements at the metaphase of the first meiotic division. F_2, F_3, and F_4 plants showed 69-70 somatic chromosomes.

Hybrids, using two varieties of *S. tuberosum* as females and *S. Antipoviszii* as the male parent, were found to have 72 somatic chromosomes but were completely sterile.

Ivanovskaja of the U. S. S. R. (12) discusses a haploid plant of *Solanum tuberosum*. In the cross between *S. tuberosum* var. Aurora ($2n = 48$) x *S. Rybinii* Jux. et Buk. ($2n = 24$) a plant with a somatic chromosome number of 24 was produced, possessing none of the characters of *S. Rybinii* and differing in several respects from Aurora. In both the hybrid and the female parent two embryo-sac mother cells were found, and it was concluded from this and other evidence that the haploid had arisen apogamously from one of these, stimulated by its twin which had possibly been fertilized. Pairing was practically normal in the haploid, but the reduced gametes were not functional.

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REPORT OF THE TWENTY-SEVENTH ANNUAL MEETING OF THE POTATO ASSOCIATION OF AMERICA

The twenty-seventh annual meeting of the Potato Association of America was held in Philadelphia from December 27 to 31, 1940. Sessions were held in Room 313, Engineering Building, University of Pennsylvania and joint sessions with the American Phytopathological Society in the Hotel Philadelphian and with the American Society for Horticultural Science in Room 313, Engineering Building. The following officers were elected and committees appointed:

President, F. M. Blodgett, Cornell University, Ithaca, New York.

Vice-President, F. J. Stevenson, U. S. Dept. of Agriculture, Washington, D. C.

Secretary-Treasurer-Editor, Wm. H. Martin, Agricultural Experiment Station, New Brunswick, New Jersey.

Executive Committee, C. H. Metzger, California; E. B. Tussing, Ohio State University, Columbus, Ohio; E. J. Wheeler, Michigan State College, East Lansing, Michigan; J. G. Richard, Louisiana State University, Baton Rouge, Louisiana.

Certification Committee, Marx Koehnke, *Chairman,* Alliance, Nebraska.

Committee to Coordinate Research on New and Unusual Potato Diseases, J. G. Leach, *Chairman,* West Virginia.

Potato Variety Nomenclature Committee, C. F. Clark, *Chairman,* U. S. Department of Agriculture.

Potato Breeding, F. J. Stevenson, *Chairman,* U. S. Department of Agriculture.

Cultural and Storage Investigations, E. V. Hardenburg, *Chairman,* Cornell University.

Fertilizer Investigations, Ora Smith, *Chairman,* Cornell University.

Virus Diseases, T. P. Dykstra, *Chairman,* U. S. Department of Agriculture.

Potato Insects, W. A. Rawlins, *Chairman,* Cornell University.

The following committees were appointed to serve during the meetings:

Auditing Committee, E. J. Wheeler, *Chairman,* H. F. Bailey, K. G. Buckley.

Nominating Committee, J. R. Livermore, *Chairman,* John Bushnell, E. V. Hardenburg.

Resolutions Committee, H. O. Werner, *Chairman,* J. C. Miller.

Report of the Secretary-Treasurer

The membership in the Potato Association of America is now 1517, a slight decrease from 1939, when the membership was 1565. It is unfortunate that a larger number of our progressive potato growers in the different states are not acquainted with the American Potato Journal. If they were there is no question but that the membership in the Association could be greatly increased. Your Secretary cannot hope to carry on all of the activities of the Association alone. He must have your cooperation if he is to maintain the membership and the American Potato Journal.

This year the Journal was made up of 339 pages of printed and 78 pages of advertising, a very slight increase over last year.

Statement for the year ending December 28, 1940:

Receipts

Balance from Dec. 21, 1939	$70.59
Annual Dues	1,318.81
Sale of Advertising	1,342.13
Reprint Receipts	187.08
Miscellaneous	143.91
TOTAL RECEIPTS	$3,062.52

Expenditures

Printing and Mailing of Journals (October 1939 to Sept. 1940, incl.)	$2,003.51
Reprints	226.55
Miscellaneous	63.68

Secretarial Work	240.00
Stenographic Services	319.00
Stamps and Supplies	205.54
TOTAL EXPENDITURES	$3,058.28

Bank Balance December 28, 1940—$4.24.

Accounts Receivable

Reprints	$49.48
Miscellaneous	27.60
Back Issues	55.25
TOTAL ACCOUNTS RECEIVABLE	$132.33

Accounts Payable

October issue	$169.57
November issue	178.28
Reprints and Supplies (Nov.)	25.20

Report of the Auditing Committee

We the undersigned auditing committee, have examined the books of the Potato Association of America and have found them to be in good order.

E. J. Wheeler, *Chairman*
H. F. Bailey
K. G. Buckley

Report of the Committee on Resolutions

Resolved: That we extend a vote of thanks to the officers of the A. A. A. S. and the University of Pennsylvania for the facilities provided for these meetings.

That we extend a vote of appreciation to Secretary Martin for his continued efficient conduct of the business of the Association.

That we urge the U.S.D.A. and state experiment stations to conduct a coordinated research program to determine basic facts regarding the control of bacterial ring rot with special reference to determining practical recommendations for seed certification procedure.

That potato breeders are requested to follow the recommendations of the nomenclature committee in naming new varieties and that this committee give thought to the possibility of developing a national system of testing, describing, and naming new varieties.

H. O. Werner, *Chairman*
J. C. Miller

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POTATO FERTILIZER AND NUTRITION STUDIES IN 1940[1]

ORA SMITH

Cornell University, Ithaca, N. Y.

Results of investigations published in 1940 and the latter part of 1939 on fertilizers, fertilization, cover crops, green manures, rotations, soil reaction, soil fertility and sand and solution cultures with the potato are summarized briefly in this report. The material on these subjects is not claimed to be complete. Some references which have not been abstracted in this review are included in the bibliography with the literature citations for the benefit of those desiring a more complete bibliography on this subject.

Toevs and Baker (54) found, in Idaho, that if the soil contains well balanced amounts of nitrogen, phosphorus and potassium, phosphorus fertilization for potatoes is not desirable. However, when potatoes follow legumes which are heavy phosphorus feeders and the phosphorus has not been replaced, the further additions are profitable.

Thomas and Mack (52) report that the law governing the absorption of calcium, magnesium and potassium is a linear function in time. The equilibrium CaO-MgO-K_2O on any sampling date is expressed as a composite Ca-Mg-K unit derived after the manner of the N-P-K unit. The units so obtained are plotted in trilinear coordinates. The graphs are used to show the interrelationship of the various base deficiencies and as a diagnosis of the

[1]Department of Vegetable Crops, Cornell University, Ithaca, New York.

mode of adaptation of the soil to the needs of the plant with respect to Ca, Mg and K.

Thomas and Mack (51) report no direct relationship between the nitrogen content of the leaves and yield. The effect of nitrogen on the yield was governed by the presence of phosphorus and potassium. A relationship existed between the phosphorus and potassium in the leaves and yields. A low intensity of nutrition (sum of N, P_2O_5 and K_2O content of leaf as percentage of dry weight) was always associated with low yields, but owing to luxury consumption of potash, high intensities were not always associated with high yields, although high yields were always associated with adequate intensity. The course of nutrition with respect to N, P and K during the growth cycle is described with the aid of graphs which show in trilinear coordinates the equilibrium between N-P_2O_5-K_2O in the chosen leaf at each sampling date for the different fertilizer treatments.

Smith (43), in a general review of potato growing in Europe, states that where potato growing is not conducted on an extensive basis and where animal manure is available, it is used at the rate of approximately 12 tons per acre. One ton of 4-3-12 or 4-4-14 fertilizer per acre is quite a common application. The best growers in Holland apply two tons of commercial fertilizer to the acre. Late potatoes in England are often supplied with 1350 to 1500 pounds of 7-6-11 fertilizer to the acre.

In eastern Germany the most common rotation is (1) potatoes, (2) rye. Longer rotations ranging from 5 to 10 years' duration are most common in other sections of Germany.

Schurig (42), in Germany, found that on calcareous peaty sand and higher sandy loam, manuring in spring was always better than in the fall. Yields indicated that prompt covering after spreading manure is most important. With spring application, more NH_3 is available to the crop at a critical period. Spring plowing is more favorable in that the soil is thereby more warmed and aerated than after lying plowed over winter. The starch content of potatoes was reduced more by manure applied in spring, owing to the greater amounts of available nitrogen and chlorine in the soil during the growing season. This effect was reduced by using a low chlorine potash carrier. Manure was essential for maximum yields on these soils; plots with equivalent chemicals were less productive.

Prince *et al* (38), in New Hampshire, found that omitting potash caused the greatest reduction in yield, with phosphoric acid

second and nitrogen third. When each of the elements are doubled from 1 ton 4-8-7, phosphoric acid caused a greater increase than the nitrogen or potash, with nitrogen causing the lowest increase. The authors recommend a 2-5-5 or a 1-3-3 ratio for potatoes. Highest yields with 4-8-7 fertilizer were obtained with applications of 1½ tons, with lower yields at 1 ton and ½ ton.

The use of lime in conjunction with a fertilizer carrying no potash had a depressing effect upon yields indicating that lime ties up potash that would otherwise be available to the potato crop. Magnesium did not affect yields appreciably and the use of boron does not seem to be warranted under the conditions of their tests.

Double strength fertilizer caused a significant increase in yield over single strength when equal amounts of plant food were used. Banding the fertilizer along the sides of the row gave a slight increase compared with broadcasting.

Shorter, blockier potatoes were produced with high potash applications, whereas high phosphorus reversed this trend, a trend which was accentuated by omitting the potash.

Morton (30) obtained large increases on the Isle of Ely from 450 pounds ammonium sulfate and 1000 pounds superphosphate in addition to 200 pounds potassium sulfate per acre and 10 tons farmyard manure. Where 8 tons of farm manure had been applied, 150 pounds $(NH_4)_2SO_4$ gave an increase of 1½ tons potatoes per acre. Three hundred pounds $(NH_4)_2SO_4$ and 500 pounds superphosphate increased the yields 2 tons above where 200 pounds of potassium sulfate was used alone. On another farm, highest yields were obtained from 300 pounds ammonium sulfate, 1000 pounds superphosphate and 200 pounds potassium sulfate per acre.

Three hundred pounds ammonium sulfate and 400 pounds sulfate of potash per acre increased the yields 2¾ tons compared with the use of 800 pounds superphosphate alone. Sulfate of potash in this part of the country is used rather to improve the quality of the potatoes than to increase the yield.

Millar (28) states that years of experimental work in Michigan have shown that a fertilizer should contain from one-half to as much potash as phosphoric acid for Michigan soil conditions. On the heavier soils, such as the heavy sandy loams and loams, the lower proportion of potash is satisfactory; but, on the lighter sandy loams, potash content should equal phosphoric acid content. The recommended grades are 4-16-8 and 3-12-12.

Mattingley (25) reports that for a period of years in Australia,

300 pounds superphosphate and 200 pounds sulfate of ammonia per acre have produced 1200 pounds more potatoes per acre than the same amount of superphosphate but only 100 pounds sulfate of ammonia. In some sections, however, 100 pounds sulfate of ammonia with 300 pounds superphosphate produces highest yields. Superphosphate alone increases yields as much as 50 per cent over the unfertilized, but less than when nitrogen is added.

Mattingley (26) shows that in certain sections of Australia the most profitable fertilizer is 600 pounds per acre superphosphate and 100 pounds sulfate of ammonia. There is a very definite lack of response to the application of potash in most sections. In the Neerim section, however, potash appears to have a definite beneficial effect on the yield of potatoes, whereas sulfate of ammonia seems to be of little or no value.

Later Mattingley (27) has shown that in the Coragulac section of Australia that the use of artificial fertilizers seems to be of no advantage during a three-year period, 1937-1940. In the Illowa area the optimum fertilizer seems to be 400 pounds superphosphate only.

Kurchatov *et al* (23), in Russia, found that on light soils potatoes utilized NH_4 and K fertilizers best when they were applied in several doses. On heavy soils, the $(NH_4)_2SO_4$ should be plowed under as deep as possible. Nitrogen and potash fertilizers, especially KCl and sylvanite, reduced the percentage of starch in potatoes. The nearer to the blooming period the N and K fertilizers were used the less starch was present per unit weight in the potatoes.

Jacob and Gottwick (20) conducted experiments with potatoes in Germany from 1930 to 1936 on sandy soil receiving different fertilizer treatments as follows: control, nitrogen and phosphorus, complete fertilizer with potash in different forms; namely, $K_2Mg(SO_4)_2$, K_2SO_4, kainite, 40 per cent manure salts and KCl. The beneficial action of potash on yields was slight during the first year but increased each year thereafter with $K_2Mg(SO_4)_2$ giving best results. No change occurred in the mineral contents of the fertilized plants except that the potash content of the foliage was higher in the plants receiving high amounts of potash.

Hill and Roach (15) grew plants in sand culture deficient in one or more of the elements: nitrogen, phosphorus, potassium, calcium, magnesium and boron and injected the plants with solutions containing the deficient element. The plants responded to all the elements injected. The response was local or general ac-

cording to the injection method used. Their methods enable diagnosis of deficiencies to be made in 7-21 days and provide means of rapidly, and without injury, making good any deficiency to which the plant has been subjected.

Edmundson (10) states that commercial fertilizers are not generally used in potato production in the western states. In the Stockton district of California large quantities of phosphorus and potash are applied with beneficial results and in Kern County nitrogen fertilizers are applied. In Montana, phosphate fertilizer has been found to be beneficial, also in some parts of Wyoming, Colorado, Nebraska and New Mexico. In most districts, nitrogen is supplied by plowing under alfalfa, sweet clover or other leguminous crops. Many growers apply large quantities of manure during the winter previous to potato planting or to some other crop in the rotation.

Cox and Odland (8) grew potatoes two years on plots which had received nitrogen for more than 40 years from either nitrate of soda or ammonium sulfate. All yields were considerably better following ammonium sulfate on the well-limed plots but only small differences between the two nitrogen carriers were noticeable on the plots without lime. With $(NH_4)_2SO_4$ there were marked increases in yield by the use of lime, whereas the yields after nitrate were as great, if not somewhat greater, on the unlimed plot.

Phosphorus carriers compared on the basis of equal rates of P_2O_5 ranked as follows from highest to lowest yields, triple superphosphate, basic slag, superphosphate, ground bone and rock phosphate. The yields were significantly lower on plots receiving one-half the normal application of P_2O_5 in superphosphate.

Comparing muriate of potash, sulfate of potash, kainite and potassium-magnesium sulfate as carriers of potassium, they obtained highest yields from sulfate of potash and lowest from kainite.

In 90 per cent (3) of approximately 50 experiments in England over a 6-year period, there was a definite response to ammonium sulfate even on fen-land soils which are rich in nitrogen. The general response to nitrogen was about 1500 pounds of potatoes for each 100 pounds sulfate of ammonia applied. Each 100 pounds superphosphate increased yields nearly 800 pounds. Potash gave definite increases in approximately one-half the trials, but was vitally important where deficient. On light and light fenland soils, 200 pounds per acre sulfate of potash yielded as much as 3 tons more potatoes.

Weigert and Gleissner (62) in Germany obtained 41 per cent increase in yields of potatoes with applications of 90 pounds N per acre compared with no nitrogen, but with standard applications of phosphorus and potassium in both cases.

Daines and Martin (9) compared sources of nitrogen in a 4-8-7 fertilizer. They found that nitrogen supplied from a combination of organic and inorganic forms, together with the treatment in which the nitrogen used consisted of two units each of sodium nitrate and ammonium sulfate, produced the highest yields. There was no correlation between yields and acidity or basicity of the fertilizer used except where sodium nitrate supplied all the nitrogen, in which case the alkaline mixture outyielded the acid combination in three of four tests. The continued use of nitrate of soda as the sole source of nitrogen has resulted in a higher percentage of scabbed potatoes.

Boischot and Herviaux (7) found that on granitic soils of Brittany the use of nitrogenous fertilizers is advisable on potatoes to the amount of applications of 55 pounds per acre.

Allison (2) states that about 50 per cent of the N in a mixed fertilizer for potatoes may be derived from urea instead of from natural organic sources without appreciably affecting the yield when the remainder is supplied by a combination of $NaNO_3$ and $(NH_4)_2SO_4$. The use of natural organic materials as 20 per cent of the N source when the balance of this element is supplied by a mixture of equal parts of urea and $(NH_4)_2SO_4$ did not affect the yield of tubers as compared either with the check treatment or the all-urea mixtures. No stimulation in growth of vine or consistent increase in yield of tubers could be attributed to the use of a mineral supplement consisting of manganese, zinc and boron.

Hundertmark and Allison (17) found in experiments on Bladen fine sandy loam and Portsmouth fine sandy soils that 50 per cent of the N in a mixed fertilizer for potatoes was derived from urea instead of natural organic sources, with the other one-half supplied as $NaNO_3$ 15 per cent, and $(NH_4)_2SO_4$ 35 per cent, without appreciably affecting the yield. The use of 20 per cent of the N in the form of natural organic compounds, when the balance was supplied by a mixture of equal parts of urea and $(NH_4)_2SO_4$, did not affect the yield of tubers as compared with either the check treatment or all-urea mixtures, though it did favorably influence the physical condition and the drillability of the mixture. No stimulation in growth of vine or consistent increase in yields of

tubers could be attributed to the use of a mineral supplement of manganese, zinc, or boron.

Willis and Harrington (63) report that potatoes in all parts of Montana responded well to phosphorus fertilization. About 125 pounds per acre treble superphosphate is recommended for most locations. Raw rock phosphate, even if finely ground, was of little value for potatoes.

Sugawara (49), working in Japan, found that in plants deficient in potash the leaves became dark green, then yellowish brown at their edge, gradually curled down and finally dried up. Increased potash supply caused no marked effect on the ratio of length to diameter of tubers, but had a beneficial effect on the size and yield of tubers. Starch accumulation in the tubers was increased by a heavy application of potash and was lowered by potash starvation. The growth of tubers and also of their starch grain was directly proportional to the amount of potash added to the soil.

Pevzner (35) presents results of tests conducted for 4 years on heavy clayey soils in Russia. The best form of potash fertilizer is K_2SO_4 which gives maximum yields of tubers and starch. Sylvanite and Carnallite are the least advantageous fertilizers for potatoes. The 40 per cent K salts occupy an intermediate position.

Turner (56) computed the results of experiments in England comparing the effects of (1) farmyard manure, (2) Adco compost, (3) straw and artificials, (4) superphosphate, and (5) rock phosphate on potatoes in a four-year rotation of potatoes, barley, rye grass and wheat. Farmyard manure and straw and artificials were better than Adco. Superphosphate was better than rock phosphate.

Turlapova (55) states that green manure in the form of lupine enriches the soil in organic matter and thus creates conditions favorable to the accumulation of starch in potato tubers. Moreover, the starch yield per acre can be increased by applying mineral fertilizers to the lupine rather than to the potato crop.

Smith and McCubbin (46) obtained highest yields in two sections of New York State in rotations in which potatoes are grown every year and which receive 12 tons of manure to the acre annually, in addition to 1000-1200 pounds 5-10-5 fertilizer. The highest yielding 2-year rotation was one in which potatoes follow a one year sod of clover and timothy grown for green manure. Lowest yields were obtained in the rotation in which potatoes followed dry shell beans or soybeans for hay in a 2-year rotation. In another section of the state, no significant differences in yields were ob-

tained between any of the rotations in 1937 or 1938. In 1939, the highest yielding rotations were of 2 years' duration, potatoes following corn for green manure and potatoes following dry shell beans. Manure applications in this section have not significantly increased yields over similar rotations to which manure was not applied. Extremely low yields were obtained in the Northern New York plots when potatoes were grown every year in the same soil without commercial fertilizer, manure or cover crop. In the Central-Western New York plots such rotations until 1939 yielded as well as any other plots.

Prince *et al* (38) conducted two 3-year rotation experiments of potatoes, oats and mixed hay and potatoes, oats and clover with all of the fertilizer applied to the potato crop. These rotations failed to maintain the organic matter level which existed at the beginning of the experiment. High phosphorus treatment appeared to reduce the organic carbon loss. Omission of phosphorus resulted in a loss of organic carbon more than twice that from the high phosphorus treatment. Liming had a favorable effect on the organic carbon level.

Berkner *et al* (4) state that under present economic conditions in Germany, growing any crop only to be plowed under for green manure is not to be encouraged. A non-bitter variety of lupine is now available, which is relished by stock and equal to the old varieties in all other respects; when fed and the manure returned to the soil, its net value is greater than if plowed under. Crimson clover is even more valuable, as it is a good hay crop and the roots remaining in the soil contribute about four times as much organic matter and N as do lupine roots and stubble. Potatoes do especially well after crimson clover.

Tinley and Bryant (53), in a 3-year experiment on successive crops of mangels, potatoes and wheat, found that shoddy, hoof and horn meal, castor meal and dried poultry manure gave results inferior to farmyard manure when applied on an equivalent N basis, but when these materials were supplemented with inorganic fertilizers to contain equivalent P and K the results were similar to those obtained with farmyard manure. All the fertilizers, as well as the farmyard manure at the rate of 8 tons per acre, were applied only in the first year of the experiment. A complete mixture of inorganic fertilizers adjusted to provide equivalent N, P and K to the organic materials, but applied in 3 dressings each equivalent

to 1/3 of the organic fertilizer dressings, gave the highest yields in the second and third years of the experiment.

Weigert and Furst (61), in Germany, found that $CuSO_4$ dusted at 70 and 140 pounds per acre and sprayed in 3 per cent solution produced no appreciable effect on yield of potatoes. Addition of 70 pounds per acre, 140 pounds per acre and 10 per cent solution of $MnSO_4$ produced yields respectively of 1.3, 1.5 and 1.5 times the untreated. Copper and manganese were not effective on potatoes in laboratory experiments. Large and repeated field experiments in 1938 showed that the highest yield of potatoes was obtained by addition of $MnSO_4$ at 55 pounds per acre plus commercial fertilizer containing 40-45 pounds N per acre, 55 pounds P per acre and 110 pounds K per acre. The addition of $MnSO_4$ at 73 pounds per acre generally decreased the yield and $CuSO_4$ was inactive. The use of boron as boron containing superphosphate gave a less increased yield of potatoes.

Teakle and Morgan (50) working in Australia found that on the marly peat soils of the coastal swamps in the Albany district, manganese sulfate is likely to benefit a variety of crops. Copper, in addition to manganese, may be beneficial with some. Copper sulfate or manganese sulfate applied at rates of 15 pounds per acre are sufficient, and lower rates may be adequate. The residual effect of minor elements in the soil is observed in the growth of the crop grown the following year.

Van Schreven (41) showed the effects of iron, zinc, sodium, and chlorine in various concentrations on the growth of several potato varieties in Holland. Plants suffering from phosphorus, boron or zinc deficiency simulate primary leaf roll symptoms. True leaf roll, however, can be differentiated from nutritional disorders by phloem necrosis in which the dead sieve tubes react to phloroglucin and HCl by a red coloration absent from the disorganized tissues of plants affected, for instance, by lack of boron. In several cases of boron deficiency, the damage is not restricted to the phloem as it invariably is with the leaf roll. Medullary necrosis caused by calcium deficiency is stated to occur sporadically in Holland.

Boischot *et al* (6) found in France that the addition of sulfur in the form of ammonium sulfate, potassium sulfate or calcium sulfate (superphosphate) gave increased potato yields. The sulfur of the superphosphate was most effective as it was not removed from the soil so rapidly as the sulfur from ammonium sulfate or potassium sulfate and consequently remained in contact with the plant roots for a longer time. In

calcareous soils, the superiority of K_4SO_4 over KCl was caused in large part, by the presence of the sulfur.

White-Stevens and Wessels (64) state that with a 5-10-5 fertilizer on Long Island for 2 years that 1500 pounds to the acre was the optimum application. Irrigation developed the effect of 2000 pounds per acre to a point where it was significantly greater than the 1500 pounds per acre. Wide spacing, 15 inches in the row, was best at low fertilizer applications; whereas close spacing, 11 inches, gave highest yields at 2000 pounds per acre.

When fertilizer and seed spacing are considered in conjunction with irrigation, there was considerable interaction at low levels of fertility, this interaction becoming less and associated with higher and more uniform yields as the fertility level rose. The efficacy of the irrigation attained its maximum at 2000 pounds per acre at the 11-inch seed spacing. No interrelation was found between fertilizer applied, irrigation, seed spacing, and season.

Martin and Campbell (24) in New Jersey compared varying rates of nitrogen and in some cases with a portion of the nitrogen being broadcast before plowing. Broadcasting small amounts of nitrogen before planting the cover crop is also being tried. The "Hi-Lo" method of fertilizer application with different percentages of the fertilizer at the high or low position and experiments where the phosphorus is placed in the center of the row with the seed and the mixture of nitrogen and potash applied at the sides are being conducted. In some cases, part of the fertilizer is applied in liquid form.

Starch, ash, K_2O and P_2O_5 were determined in three series of analyses on potatoes by Schmarl (40). The starch content increased with increase in K content of the plant.

Salgues (39) presents results for water, fatty material, protein, cellulose, ash, carbohydrates, dextrin and starch content for 5 varieties of potatoes grown with various fertilizer additions.

Knowles, Watkins and Cowie (22) made a study in England of the effect on potato plants of applications per acre of (1) 5 cwt. superphosphate; (2) 3 cwt. $(NH_4)_2SO_4$; (3) 1.5 cwt. $(NH_4)_2SO_4$ plus 5 cwt. superphosphate; (4) 3 cwt. $(NH_4)_2SO_4$ plus 5 cwt. superphosphate; and (5) 3 cwt. $(NH_4)_2SO_4$ plus 5 cwt. superphosphate plus 3 cwt. K_2SO_4 to a field on glacial sand and gravel to which no K fertilizer had been added for some years. Fertilizer treatment affected dry-matter content of tops but not of tubers. There were indications of premature ripening of the plants from all other treatments when compared with No. 5. Treatment No. 4 induced the earliest ripening.

Balanced fertilizing resulted in tubers in which the N content of dry matter declined with age. The use of potash lowered the N, P_2O_5 and Ca contents and increased the Cl content of all parts of the plant and maintained a much higher and more constant concentration of K_2O in tops and roots. With unbalanced fertilizing, the N content of the tubers was more constant. Fertilizing with N only raised the content of K_2O in the dry matter of all parts of the plant. N, alone or in combination, raised the N content and lowered the Ca; Cl in conjunction with N depressed the concentration of K_2O in the dry matter of all parts of the plant. Plants of treatment No. 4 were the first to attain their maximum uptake of all nutrients at a time when plants of treatment No. 5 had absorbed only 40 per cent of the quantities finally noted. No losses of elements were observed in the plants which received treatment No. 5, but losses of Ca and Cl occurred in all other plants. A significant loss of K_2O occurred in plants of treatment No. 2 and a highly suggestive loss of P_2O_5 occurred in plants of treatment 4. Fertilizer treatment had little effect upon the proportionate distribution of nutrients in parts of the plants with the exception of treatment No. 5 in which a lower proportion of K_2O was transferred to the tubers. With all treatments a high and constant proportion of Ca remained in the tops. The symptoms of scorch and premature dying off of tops which occurred on soils deficient in K_2O, when fertilized with N plus P_2O_5, was shown to be caused by decreased absorption of K_2O, which the interaction of these 2 elements induced. By increasing the soil N the adverse effects of the combination became more pronounced.

Grechushnikov (13) found that the sistoamylase activity of the potato increased by K fertilization either alone or in combination with other fertilizers; it decreases under N and P fertilization and when the day length is curtailed to 8 hours.

Two varieties, Lorch and Woltman, were raised by Akhromeiko (1) in two separate localities on different soils in Russia with and without fertililizer, to ascertain the rate of increase of organic matter and starch during growth in the leaves, stems and tubers of potato. On poor soil and closely sown, potatoes mature earlier than on medium or rich soil and give a good yield. When grown on rich soil and widely spaced, the yield is much higher but if on the same soil the spacing is close the starch is accumulated in overdeveloped stems and leaves, whereas the formation of tubers is retarded often causing an inadequate yield. The starch content in the tubers rose continuously, while in the leaves and stems it rose only during the fall, since in that season the day time temperature suffices for the synthesis of starch by the leaf, but at night the

lowered temperature reduces the flow of starch into the tubers. The percentage of N and P_2O_5 in the plant, as a whole, reached a maximum one month before harvest, then decreased. In tubers their absolute content continued to rise until harvest. On fertilized soil the maximum absorption was reached at the end of July, on unfertilized soil a month later. The percentages of K, Ca and Mg in stems, tubers and roots steadily decreased. However, their absolute contents in tubers and in the plant, as a whole, steadily rose.

Smith and Nash (47) found that 1500 pounds per acre applications of 5-10-5 fertilizer produced tubers of lower specific gravity and of less mealy texture than those of lower application or no fertilizer treatments. Applications of 1000 pounds per acre of 5-10-5 fertilizer resulted in tubers of lower specific gravity and less mealiness than applications of fertilizer with less potash. Applications of 1000 pounds per acre of 5-10-5 fertilizer in addition to the amount of nitrogen, phosphorus and potassium in a 12 ton per acre application of manure resulted in tubers with lower specific gravity and less mealy texture than those produced with lighter applications.

Soils of reaction of pH 6.36 produced tubers of lower specific gravity and less mealy texture than soils of higher and lower pH. The mealiest tubers and those of highest specific gravity were grown in soils of pH 7.88.

Of the 10 rotation systems, the highest specific gravity and most mealy tubers of the Green Mountain variety were grown on plots where potatoes are grown every year and receive no fertilizer or cover crop. Lowest specific gravity and least mealy tubers were obtained following soybeans harvested for hay.

Nash and Smith (31) in studies of potato quality grew potatoes under two light conditions at six fertilizer treatments. The no fertilizer treatment produced tubers with highest specific gravity and highest per cent of starch and dry weight and the most mealy. Tubers grown in plots receiving nitrogen were not so mealy as those which received no nitrogen. Tubers grown in shaded plots which received no nitrogen showed very little discoloration whereas those shaded plants receiving 100 pounds N to the acre showed marked darkening after boiling.

Blood and Prince (38) show that fertilizers have a slight effect on potato quality, high phosphorus tending to increase and high potash tending to decrease quality ratings.

Nikolaev (32) reported that a N to K ratio of 1:2 (and more) in the fertilizer will eliminate the darkening of sliced potatoes.

Blood and Haddock (5) state that as compared with the results obtained with a 4-8-7 fertilizer mixture, the average relative yield was increased but the cooking quality of the tubers was decreased by the use of a 4-8-14 mixture in a 6-year experiment, whereas with a 4-16-7 mixture the yield and cooking quality were both increased. Potatoes that received no fertilizer showed the highest cooking quality, but produced the lowest yields. A small amount of boron in the fertilizer seemed to improve the general external appearance of the tubers but did not increase the cooking quality.

Smith (45) found that the total yields of potatoes were lower in plots of high pH than in the more acid soils, and the yields of scabby potatoes were lower at both low and high pH values than at intermediate values. At every range of reaction, the yields were much higher following green manure crops than those following potatoes. All yields of non-scabby tubers were higher at each pH value following green manure than following potatoes, whereas the per cent of scabby tubers at each pH value following green manure was lower than that following potatoes. In general, the pH of the soil in which the green manure was incorporated was lower in July, 1939 than in soil that had grown potatoes every year.

Jacob (21) found that the border effects follow closely the actual differences between adjoining treatments. Border effect is an important factor in yield of the outside rows of fertilizer experiments. Untreated aisles around treatment plots do not reduce the edge effect. Discarding one row from each edge of a plot will eliminate most of the border effect where there are no aisles and where the differences between treatments are small.

Wachholder and Nehring (60) grew 7 varieties of potatoes several places in Germany without fertilizers, with 18.2 tons per acre stable manure and equivalent chemicals alone and in mixture. Yields, starch content and vitamin C in raw and cooked samples at harvest in October and at intervals during storage until June were determined. The 1938 range in vitamin C with variety, 24-37 mg. per cent raw, was slightly less than previously noted, but showed the same tendency to decrease in storage. Samples in February and June contained 11-14 and 8-10 mg. per cent vitamin C respectively. Distinct differences in loss of vitamin C in cooking, as well as the initial contents were noted to be material characteristics and there were no significant indications that fertilization affects these factors, except that both vitamin C and starch contents were usually a little higher in potatoes grown without fertilization. Comparisons of the same varieties grown at different places

led to the conclusion that the soil, or possibly some other local condition, is more important with respect to vitamin C than either fertilization or variety. Potatoes grown on sandy soil pH 6.2 averaged a little higher in vitamin C than the same varieties on a humus sandy soil, pH 5.6 and nearly twice as much as the same on a humus heavy loam pH 6.8.

Yields with mineral fertilizers were similar on the first 2 soils and about 50 per cent greater on the last. Mineral fertilizers only produced the largest crops in nearly all the tests and manure only was inferior to the mixture of manure and chemicals. Some special tests with superphosphate-peaturine compost indicated better action than ordinary stable manure.

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FLOWER AND BERRY PRODUCTION BY POTATOES AS INFLUENCED BY TWO LIGHT INTENSITIES AND TWO MIDWINTER PLANTING DATES

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Some years ago it became quite apparent that certain potato production problems in Nebraska could best be solved by the development of new varieties designed to meet specific needs. However, at that time it did not appear feasible to launch a breeding program because of the infrequency with which flowers, capable of producing berries and seed, were secured on potato plants in any portion of Nebraska. Since then the work of Stevenson and Clark (3) and some of our experiences with plants in studying the physiology of tuberization indicated that potato seed could be produced during the winter or spring in a greenhouse.

In the late winter and the spring of 1937 by using supplemental light to provide a 16-hour photoperiod, a very satisfactory crop of berries was produced in the greenhouse at Lincoln by 32 lines of potatoes, the flowers of which developed during April. However, several practical difficulties to the breeding program were still present. Many blossoms dropped off during the bright hot days typical of those that are quite common in April and May. Furthermore, when flowers are pollinated at this time, the berries are not ripe until the middle or latter part of July. Difficulty has been encountered in getting such seed to germinate when it is planted in August. Planting seed during the latter part of July or first part of August is desirable in order to produce tubers in the greenhouse before March, in order to permit the seedling tubers to complete their rest period before mid-June planting time in western Nebraska. It was therefore necessary to determine the possibility of producing seed during the winter or very early spring. Experiences with the crop in the spring of 1938 indicated that light intensity might be a factor of importance—especially with varieties that cannot generally be induced to bloom.

In order to determine the value of increased light intensity during the day time as well as during the supplemental light portion of an 18-

[1]Professor of Horticulture.

[2]Published with the approval of the Director as Journal Series Number 275, Nebraska Agricultural Experiment Station, 1940.

[3]Stevenson, F. J. and Clark, C. F. 1933. Artificial light as an aid in potato breeding. Amer. Potato Jour. 10:103-107.

hour photoperiod the following experimental treatments were provided during the winter of 1938-'39 for 15 varieties:

A. Seed pieces planted Dec. 9; transplanted Dec. 24; 100-125-foot candles.
B. Seed pieces planted Dec. 9; transplanted Dec. 24; 30-40-foot candles.
C. Seed pieces planted Dec. 24; transplanted Jan. 10; 30-40—foot candles.

Lights were raised as plants grew so that they were sufficiently high to provide relatively uniform light at the tops of all plants, the place where light measurements were made.

Eight plants of the 15 varieties were grown in gravel in 4, No. 10 (gallon) tin cans (2 plants per can). A complete nutrient solution was supplied daily. The cans with each variety were systematically distributed over the bench space used by each light treatment. The "C" series was located least advantageously for receiving the midwinter sunlight. Light proof black curtains were drawn between light treatments when lights were turned on. Lights were turned on at 7 A. M. and left on until the daylight was as bright as the light from the electric lights. On dark days lights were left on all day.

In the late afternoon lights were turned on when needed and left on until 1 A. M. Night temperatures were maintained at 50-60° F., day temperatures at 60-75° F. except on some very bright hot days late in the season. The daily radiation, as recorded outside the greenhouse by the U.S.D.A. Weather Bureau instruments located at a distance of about 2000 feet, is shown graphically in figure 1.

Of the 15 varieties or lines used, only 6 set flowers that produced berries when pollinated with fertile pollen. The six lines that produced berries were the following:

Variety or Nebraska Acquisition No.	Original Numbers
A9-2	(Minnesota 41-1-1-7-6-1)
D22	(U. S. D. A. 0 8)
Katahdin	
Earlaine	
A 12	(Minnesota 75 - 5)
Mesaba	

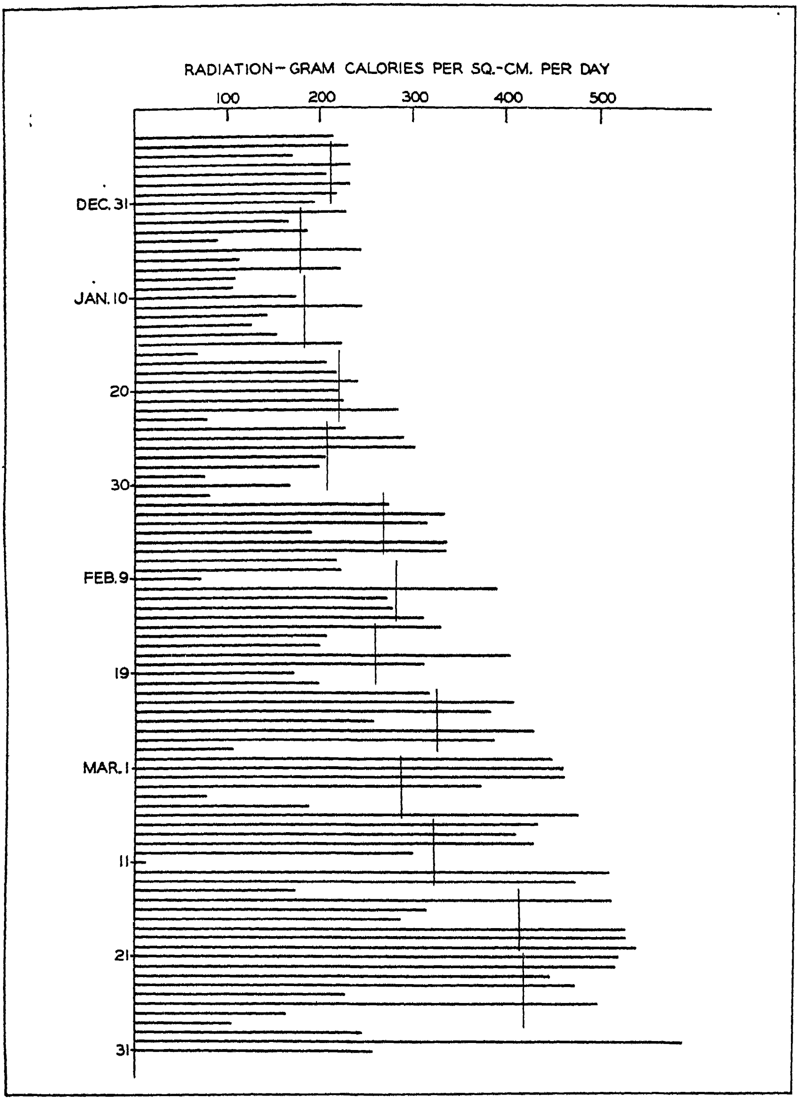

FIG. 1. Light intensity outside the greenhouse during every day from the 24th of December, 1938, to the 31st of March, 1939, as gram calories per square centimeter per day. Vertical lines indicate mean daily radiation for each week. Radiation records were procured by U. S. Weather Bureau station located about 2,000 feet from greenhouse.

The nine lines or varieties that produced no berries in any treatment were:

B4-1	(Minnesota 29.32-1-34)
B5	(Minnesota 1.33-1-34)
B6-2	(Minnesota 5.33-1-34)
B6-4	(Minnesota 5.33-8-34)
Jubel	
Red Warba	
Triumph 12	Earliest Nebraska strain.
Triumph 22	Mid-season Nebraska strain.
Triumph 23	Very late Nebraska strain.

From earlier experience we found that the lines A9-2, D22, and the Katahdin variety produce good pollen under greenhouse conditions such as were being used. Therefore, pollen from these lines was used exclusively in pollinating any flowers that opened.

Only three lines bloomed when the weakest light was used for the supplemental light of the photoperiod as shown in table 1 and figure 2. Trebling the light was of no great value with two lines, but increased blooming and berry setting about six fold with Katahdin (A). When the potatoes were planted 15 days later (Dec. 24) and only the lower intensity of light was used in the supplemental period (C) six lines bloomed and produced berries but with this treatment two lines (A9-2 and D22) which had bloomed most profusely with the other treatments did not bloom any better.

The Katahdin appeared to profit more by the bright supplemental light of treatment A than by the brighter natural daylight of treatment C. On the other hand Earlaine profited more by the brighter natural daylight and this was the only treatment that induced any bud differentiation or berry development with A12 and Mesaba.

Apparently A9-2 and D22 can be induced to bloom under conditions of very low illumination. The brightest daylight conditions of set C plus the weaker supplemental light was just beginning to be satisfactory for flower development with Earlaine, A12, and Mesaba but was entirely inadequate for all of the other varieties.

With the planting made on the 9th of December (A and B) most of the flowers developed to the pollination stage with A9-2 and D22 between the 20th of February and the 10th of March, but D22 continued to produce flowers until the 20th of April. (Fig. 2). As many of the buds or flowers of the first clusters of Earlaine and Katahdin ab-

TABLE I.—*Total numbers of flowers and berries produced on eight plants of each of six varieties which were subjected to three different light treatments.*

Variety	Light Treatment. A Early Planting — Bright Light	Light Treatment. B Early Planting — Weak Light	Light Treatment. C Late Planting — Weak Light
	Total Number of Flowers.		
D 22	127	121	108
A 9-2	39	44	47
Katahdin	71	10	53
Earlaine	5	0	12
A 12	0	0	18
Mesaba	0	2	3
	Total Number of Berries.		
D 22	87	75	63
A 9.2	27	36	33
Katahdin	51	8	14
Earlaine	4	0	8
A 12	0	0	7
Mesaba	0	2	3

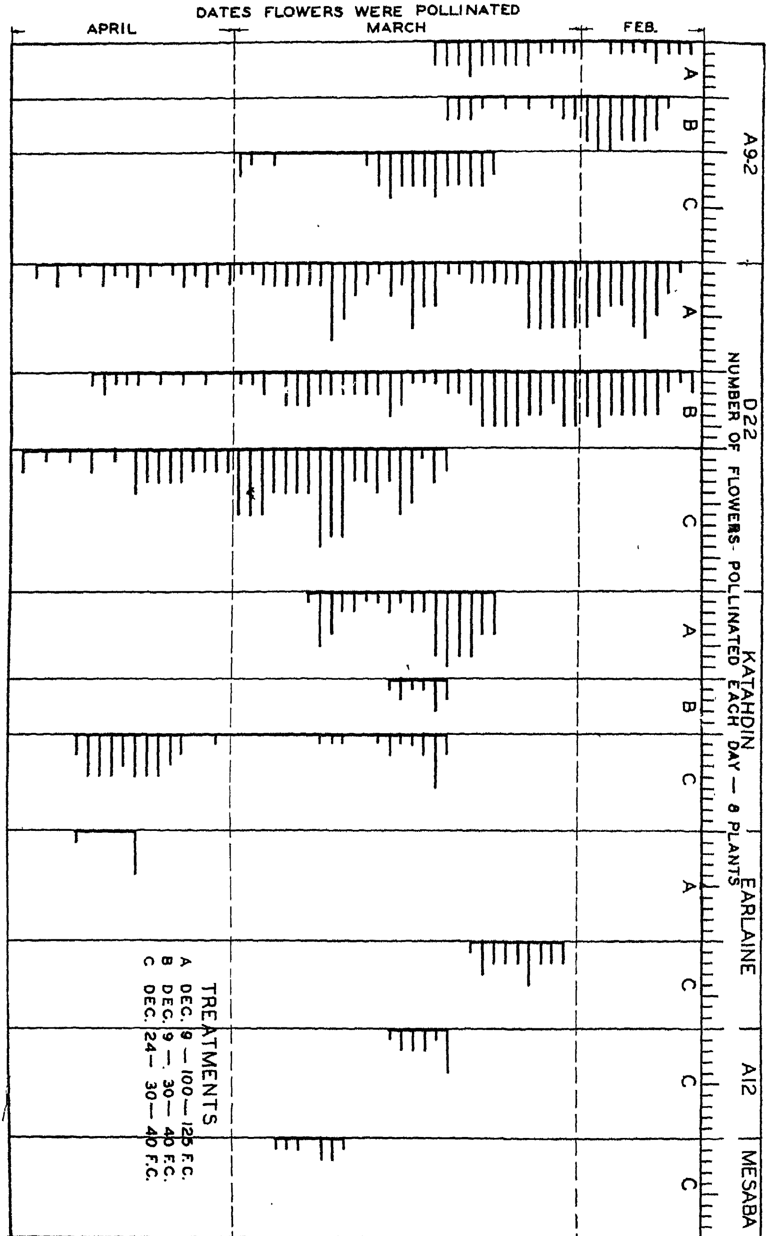

FIG. 2. Number of flowers pollinated on each date on eight plants of each variety and treatment. Each minor division indicated at top represents one flower. Letters at top of graph indicate treatments described on page 354.

scissed, most of those developing to the pollination stage were produced on the second or third clusters which accounts for their relative lateness as reported in figure 2. The time of blooming did not seem to be hastened by the use of the stronger supplemental light of treatment A.

There was little difference in the intensity of the daylight from the time of plant emergence to the pollination of the first flowers on B and C. During this time the radiation averaged 226.2 gm. cal. per sq. cm. per day with B, and 254.2 gm. cal. per sq. cm. with C. During this time plants of C of course received less supplemental light, since the days were longer. Light differences during the two weeks prior to the opening of the first flowers apparently were not of great importance. During this period with B (Feb. 7-20), the light averaged 293 gm. cal. compared with 314 for the comparable period (Feb. 21-March 6) with C. The more frequent occurrence of some very bright days (400 + gm. cal.) during the period when blossoms of C were developing may have been a more significant factor for inducing most blooming in C than the slightly greater average light for two weeks just prior to blooming. In any event, it is apparent that the difference in light for the two treatments was relatively small, but that the C treatment was supplying the minimum amount necessary to induce blooming in three varieties that did not bloom with the B treatment. There were 9 other lines that did not bloom at all. Of these 9 lines all of them bloomed during the spring of 1937, and 1938 when planted about 3 to 4 weeks later than C—that is in mid or late January or when supplied with twice as much supplemental light and a longer photoperiod than was used with A.

Conclusions

With an eighteen-hour day, flower and berry production were improved in midwinter by increasing the intensity of the light. This was accomplished by either increasing the intensity of the supplemental light or by planting later so that the plants obtained the benefit of the brighter, longer days. An increase in the average daily radiation from 226 to 254 gm. cal. per sq. cm. seemed as effective in stimulating flowering and berry production with some varieties as increasing supplemental light from about 35 to about 115-foot candles. With some varieties increased daylight intensity was more beneficial than increasing the supplemental light.

Nine varieties which bloomed in April, 1937, were not induced to bloom by any of the treatments used in this experiment.

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PROGRAM OF THE TWENTY-EIGHTH ANNUAL MEETING

OF THE POTATO ASSOCIATION OF AMERICA

December 29-31, 1941

President, F. M. BLODGETT, *Cornell University, Ithaca, New York.*
Secretary, WILLIAM H. MARTIN, *Rutgers University, New Brunswick, N. J.*

Monday Afternoon, Joint Session with American Society for Horticultural Science, December 29, 2:00 P. M.; Room 212, Hyer Hall, Southern Methodist University.

JULIAN C. MILLER, *Chairman*

1. *Importance and Prevention of Potato Seed Piece Decay.* (15 min.) O. H. ELMER, Kansas State College, Manhattan, Kansas.

2. *Non-virus Leaf Roll of Irish Potatoes.* (12 min., lantern.) E. L. LECLERG, U. S. Department of Agriculture, Baton Rouge, Louisiana.

3. *A Comparison of Seed Pieces Cut from the Apical and Stem Ends of Irish Cobbler, Chippewa, and Russet Rural Potatoes.* (15 min.) N. K. ELLIS, Purdue University, Agricultural Experiment Station, Lafayette, Indiana.

4. *Residual Effects of Phosphorus on Irish Potatoes.* (15 min.) L. M. WARE, Auburn, Alabama.

5. *Effect of Date and Depth of Planting on Yield of Irish Cobbler Potatoes.* (15 min.) W. C. BARNES, Charleston, South Carolina.

6. *The Distribution of Potato Seedling Progenies in Crosses of Pollen Sterile X Pollen Fertile Parent.* (15 min.) ZOLA M. FINEMAN, University Farm, St. Paul, Minnesota.

7. *Five Years' Data on Muck Fertilized in Excess.* (15 min.) C. L. FITCH, Iowa State College, Ames, Iowa.

Tuesday Morning Session, December 30, 9:15 A. M.; Room 106, First Baptist Church.

1. Report of the Secretary-Treasurer, Editor.

2. Appointment of Committees.

3. *Report of the Committee on Nomenclature.* P. M. LOMBARD, U. S. Department of Agriculture, Beltsville, Maryland.

4. *Report of the Seed Potato Certification Committee.* MARX KOEHNKE, Alliance, Nebraska.

5. *Potato Virus Investigations in* 1941. T. P. DYKSTRA, U. S. Department of Agriculture, Beltsville, Maryland.

6. *Potato Insect Investigations in* 1941. W. A. RAWLINS, Cornell University, Ithaca, New York.

7. *Potato Culture and Storage Investigations in* 1941. E. V. HARDENBURG, Cornell University, Ithaca, New York.

8. *Potato Fertilizers and Nutrition Studies in* 1941. ORA SMITH, Cornell University, Ithaca, New York.

9. *Symposium—Benefits Derived from Certified Seed Test Trials.* Discussion led by JULIAN C. MILLER, Louisiana State University, University, Louisiana.

10. *Benefits Derived from Southern Seed Trials.* R. C. HASTINGS, State College Station, Fargo, North Dakota.

11. *Value of Indexing and Other Greenhouse Seed Trials.* MARX KOEHNKE and JOSEPH SHAUGHNESSY, Alliance, Nebraska.

Tuesday Afternoon Session, December 30, 2:00 P. M.; Room 106, First Baptist Church.

1. Report of Committees and Election of Officers.

2. *Value of Alabama Seed Trials to Local and Out-of-State Growers.* L. M. WARE, Alabama Polytechnic Institute, Auburn, Alabama.

3. *Relation of Field Plot Design to Seed Source Tests on Irish Potatoes in the South.* (12 min., lantern.) E. L. LE CLERG, U. S. Department of Agriculture, Baton Rouge, Louisiana.

4. *Symposium—New Developments in Certifying Seed Potatoes.* Discussion led by MARX KOEHNKE, Alliance, Nebraska.

5. *New Diseases of Certified Potatoes.* A. G. TOLAAS, University Farm, St. Paul, Minnesota.

6. *New Problems Created by Ring Rot.* R. C. HASTINGS, State College Station, Fargo, North Dakota.

7. *The Southern Potato Grower and Certified Potatoes.* J. G. RICHARD, Louisiana State University, University, Louisiana.

8. *The Alabama Grower Looks at Certified Potatoes.* OTTO BROWN, Fairhope, Alabama.

9. *Louisiana Inspection of Certified Potatoes.* A. E. ANDERSON, Baton Rouge, Louisiana.

Wednesday Afternoon, Joint Session with American Phytopathological Society, December 31, 2:00 P. M.; Room 106, First Baptist Church.

R. W. Goss, *Chairman*

1. *Sterilization of Rhizoctonia sclerotia with Corrosive Sublimate.* (10 min.) O. H. ELMER, Kansas State College, Manhattan, Kansas.

2. *A Study of the Control of the Yellow-Dwarf Disease of Potatoes.* (15 min., lantern.) E. D. HANSING, Cornell University, Ithaca, New York.

3. *New Suscepts of the Potato Yellow-Dwarf Virus.* (15 min., lantern.) E. D. HANSING, Cornell University, Ithaca, New York.

4. *Soil Fauna in Relation to the Pit Scab of Potatoes.* (15 min., lantern.) A. A. GRANOVSKY and A. M. PETERSON, University of Minnesota, St. Paul, Minnesota.

5. *Plant Nutrition and the Hydrogen Ion. II. Potato Scab.* (15 min.) R. A. SCHROEDER and WM. A. ALBRECHT, University of Missouri, Columbia, Missouri.

6. *Symposium—Ring Rot and the Potato Industry.* Discussion led by R. W. GOSS, University of Nebraska, Lincoln, Nebraska.